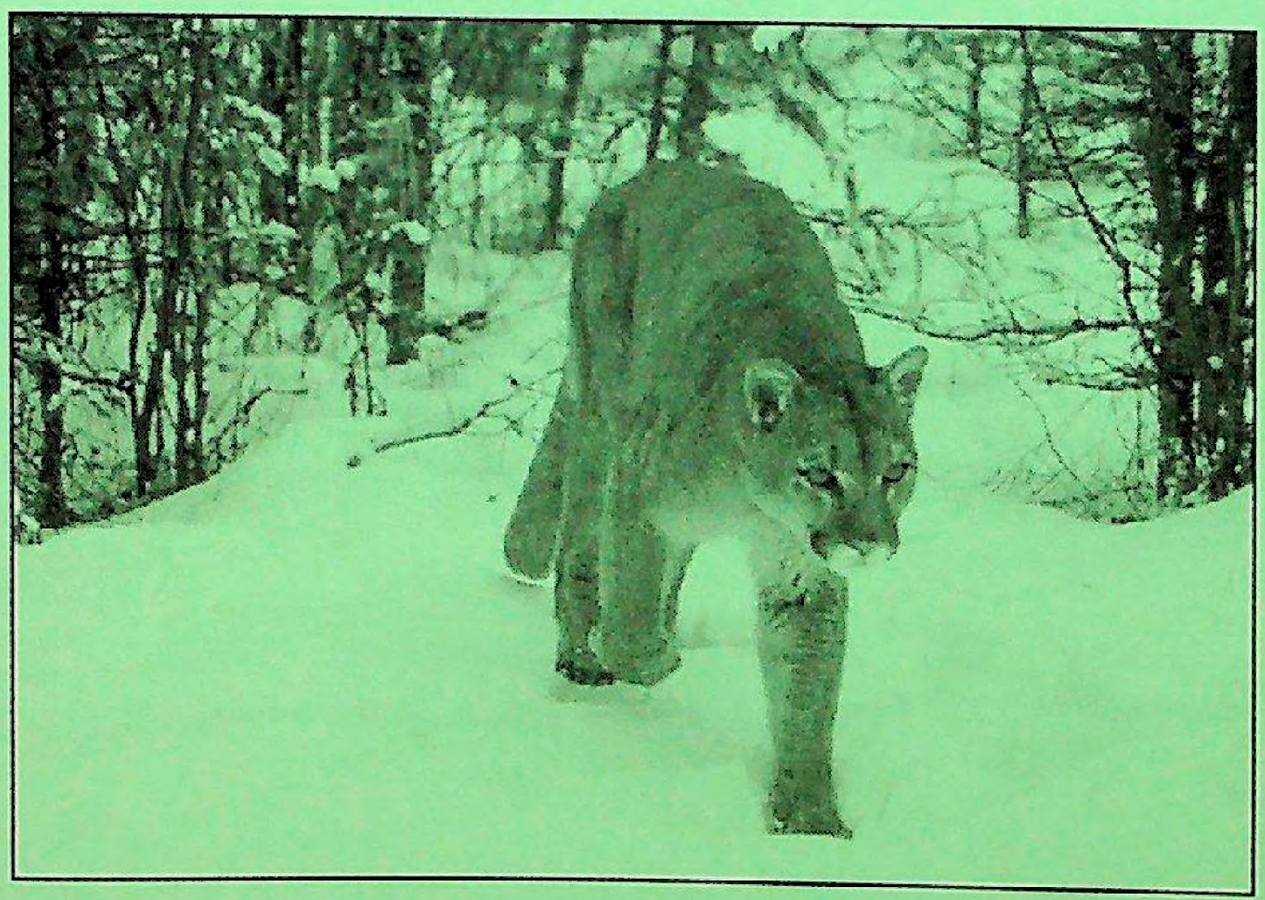
CALIFORNIA FISH and GAME

"CONSERVATION THROUGH EDUCATION"

VOLUME 87 FALL 2001 NUMBER 4



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Please direct correspondence to:

Edmund J. Pert or Todd Keeler-Wolf
Co-Editors-in-Chief
California Fish and Game
P.O. Box 944209
Sacramento, California 94244-2090
e-mail: epert@dfg.ca.gov
tkwolf@dfg.ca.gov

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CALIFORNIA FISH AND GAME

VOLUME 87 FALL 2001 NUMBER 4

Published Quarterly by

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CONTENTS

ARTICLES

Survey of Fishes and Environmental Conditions in Abbotts Lagoon, Point Reyes National Seashore, California ..... Michael K. Saiki and Barbara A. Martin 123

Analysis of Maturity in Lingcod, *Ophiodon elongatus* ..... Kelly R. Silberberg, Thomas E. Laidig, and Peter B. Adams 139

Museum Collection Records of Mountain Lions in California ..... Eric S. Long and Richard Sweitzer 153

REFEREE ACKNOWLEDGMENTS 168

INDEX TO VOLUME 87 169

COVER

Mountain lion © Willy Onarheim, 1999 Outdoor California Magazine Photography Contest.

Calif. Fish and Game 87(4):123-138 2001

SURVEY OF FISHES AND ENVIRONMENTAL CONDITIONS IN ABBOTTS LAGOON, POINT REYES NATIONAL SEASHORE, CALIFORNIA

MICHAEL K. SAIKI and BARBARA A. MARTIN
U.S. Geological Survey, Biological Resources Division
Western Fisheries Research Center-Dixon Duty Station
6924 Tremont Road
Dixon, California 95620
e-mail: michael_saiki@usgs.gov

This study was conducted to gain a better understanding of fishery resources in Abbotts Lagoon, Point Reyes National Seashore. During February/March, May, August, and November 1999, fish were sampled with floating variable-mesh gill nets and small minnow traps from as many as 14 sites in the lagoon. Water temperature, dissolved oxygen, pH, total ammonia ($NH_3 + NH_4^+$), salinity, turbidity, water depth, and bottom substrate composition were also measured at each site. A total of 2,656 fish represented by eight species was captured during the study. Gill nets captured Sacramento perch, *Archoplites interruptus*; largemouth bass, *Micropterus salmoides*; Pacific herring, *Clupea pallasi*; prickly sculpin, *Cottus asper*; silver surfperch, *Hyperprosopon ellipticum*; longfin smelt, *Spirinchus thaleichthys*; and striped bass, *Morone saxatilis*; whereas minnow traps captured Sacramento perch; prickly sculpin; and threespine stickleback, *Gasterosteus aculeatus*. Cluster analysis (Ward's minimum variance method) of fish catch statistics identified two major species assemblages--the first dominated by Sacramento perch and, to a lesser extent, by largemouth bass, and the second dominated by Pacific herring and threespine stickleback. Simple discriminant analysis of environmental variables indicated that salinity contributed the most towards separating the two assemblages.

INTRODUCTION

Very little is known about the composition of fish communities and the status of individual species inhabiting Abbotts Lagoon, Point Reyes National Seashore, Point Reyes, California. The Sacramento perch, *Archoplites interruptus*, a freshwater species native to the Central Valley drainage, was introduced into Abbotts Lagoon during the 1950s (P.B. Moyle, University of California-Davis, Davis, California, personal communication). In 1984, a fish survey by the National Park Service documented the presence of Sacramento perch; Pacific herring, *Clupea pallasi*; Pacific staghorn sculpin, *Leptocottus armatus*; anchovy, *Engraulis* sp.; striped bass, *Morone saxatilis*; and starry flounder, *Platichthys stellatus* (Self and Ranlett[1] 1984). Although Self and

[1]Self, D.W., and J.F. Ranlett. 1984. Inventory of the inland fishes and fish habitats of Point Reyes National Seashore. Unpublished draft report, National Park Service, Point Reyes, California.

Ranlett[1] (1984) speculated that black crappie, *Pomoxis nigromaculatus*; catfish, *Ictalurus* sp.; and longfin smelt, *Spirinchus thaleichthys*; were likely to occur in the lagoon, they did not actually capture these species. In 1985, seine hauls in the northernmost portion of the lagoon (also referred to as the upper lagoon) yielded "...27 Sacramento perch and nothing else" (B. Cox, California Department of Fish and Game, Yountville, California, personal communication). However, underwater observations made by scuba diving in 1989 noted "...very few organisms living in the lagoon other than arthropods and microorganisms" (Anima[2] 1990). Moreover, the lagoon "...[lacked] significant numbers of bivalves or other filter feeders" (Anima[2] 1990). It is unknown if the seeming absence of fishes resulted from the cursory nature of the underwater observations or if environmental conditions had become unsuitable for fish life.

The National Park Service is concerned that ranching operations in the watershed of Abbotts Lagoon may degrade water quality, resulting in adverse effects on fishes. This study was conducted to gain a better understanding of fishery resources in the lagoon, including the possible occurrence of tidewater goby, *Eucyclogobius newberryi*, and other federally protected fish species. Specific objectives of the study were as follows: (i) conduct an inventory of fish species inhabiting Abbotts Lagoon; (ii) determine if fishes were segregated into distinctive species assemblages; and (iii) determine if the species assemblages were associated with water quality or other environmental variables.

STUDY AREA AND METHODS

Abbotts Lagoon is a brackish coastal lagoon located on the Point Reyes National Seashore in Marin County (Fig. 1). Although usually isolated from the Pacific Ocean, the lagoon can receive seawater whenever a large sand spit is eroded by a combination of high water levels within the lagoon (due to freshwater inflows from rainstorms) and strong wave action from the ocean. According to Self and Ranlett[1] (1984), temporary breaching of the sand spit enables estuarine and marine fishes to enter Abbotts Lagoon. When the spit reforms, these fishes become trapped within the now landlocked lagoon.

In the late 1980s, the National Park Service reported algal blooms in Abbotts Lagoon that were possibly related to high nutrient inputs from dairy farms and ranches (Anima[2] 1990). The nutrients could potentially stimulate excessive aquatic plant growth and increase biochemical oxygen demand, thus creating hypoxic conditions in the lagoon that adversely affect fish.

For the present study, Abbotts Lagoon was divided into seven sampling reaches with one reach located in the upper lagoon (farthest from ocean) and three reaches each located in the middle and lower lagoons (Fig. 1). Within each sampling reach, a nearshore site and an offshore site were established at random. Sampling trips occurred

[2]Anima, R.J. 1990. Pollution studies of Drakes Estero and Abbotts Lagoon, Point Reyes National Seashore, California, USA. U.S. Geological Survey Open File Report 91-145, Menlo Park, California.

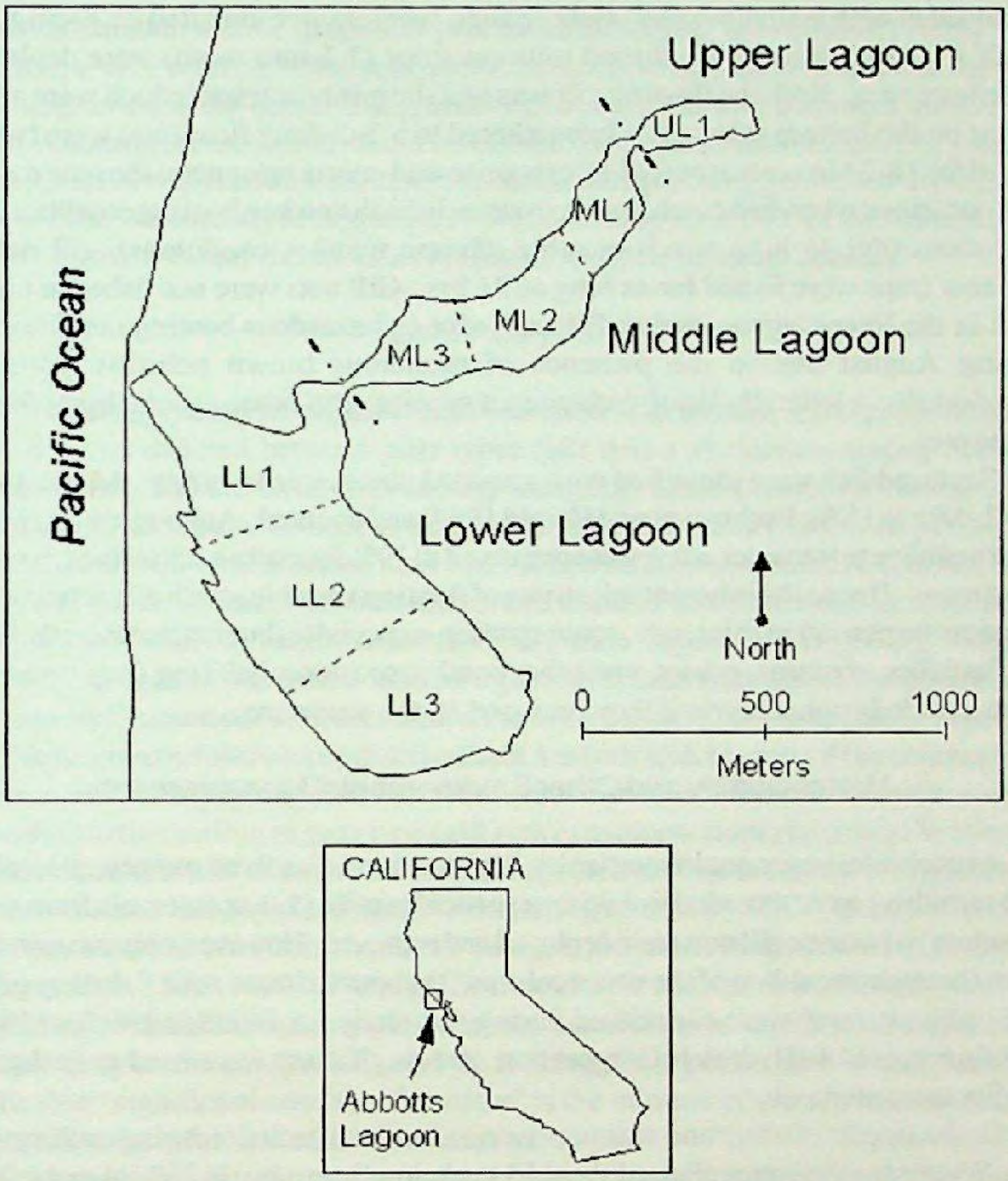

Figure 1. Map of the study area showing locations of seven sampling reaches in upper, middle, and lower portions of Abbotts Lagoon. Within each sampling reach, a nearshore site (e.g., UL1N) and an offshore site (e.g., UL1O) were selected at random.

seasonally (February 25-27/March 22-23, May 25-28, August 14-17, and November 14-17) during 1999.

Fish Collections and Related Measurements

Within each sampling reach, a 38.1-m X 2.4-m floating variable-mesh gill net (7.6-m monofilament panels with square meshes of 12.7, 25.4, 38.1, 50.8, and 63.5 mm) was

deployed at both nearshore and offshore sites, whereas five unbaited 25.4-cm X 25.4-cm X 43.2-cm rectangular-shaped minnow traps (3.2-mm mesh) were deployed at nearshore sites. Both the floating gill nets and the minnow traps (which were allowed to rest on the bottom substrate while tethered to a 2-m-long float line) were typically fished for 18-24 hrs (noon or mid-afternoon to mid-morning or noon the next day). On rare occasions when fish catches were unusually high or when boating conditions were hazardous (due to high winds or other adverse weather conditions), gill nets and minnow traps were fished for as long as 31 hrs. Gill nets were not fished at offshore sites in the lower lagoon during February due to hazardous boating conditions and during August due to the presence of numerous brown pelicans (*Pelecanus occidentalis*; a federally listed endangered species) and other aquatic birds foraging in the area.

Captured fish were identified with standard taxonomic keys (e.g., Miller and Lea 1972; Moyle 1976; Eschmeyer and Herald 1983) and counted. Although most fish were returned alive to the water, a few were preserved in 10% formalin and retained as voucher specimens. Due to the inherent selectivity of floating variable-mesh gill nets and small minnow traps used in this study, some species--especially (but not necessarily limited to) flatfishes, sculpins, gobies, and other benthic species inhabiting deep water--may have avoided capture even if they occurred in the study area.

Water Quality and Other Environmental Measurements

At each site, water quality variables (temperature, dissolved oxygen, pH, salinity, and turbidity) were recorded by taking a vertical profile (1.0-m intervals from surface to bottom) whenever gill nets were deployed and retrieved. However, only measurements from the uppermost 3-m of the water column (the approximate zone fished by gill nets and minnow traps) were considered during this study. A DataSonde® 3 multiprobe and Surveyor® 4 (Hydrolab Corporation, Austin, Texas) were used to make water quality measurements.

Grab samples of water and sediment were taken from each site during each sampling trip. Water samples were collected about 15-cm below the surface in 250-mL polyethylene bottles, acidified with two drops of 5.25 N sulfuric acid, and chilled or frozen until total ammonia (NH_3+NH_4^+) concentrations could be determined with an Orion SA270 concentration meter and an Orion No. 951201 ammonia gas-sensing electrode (Orion Research Inc., Cambridge, Massachusetts). Sediment samples, collected with an Ekman dredge, were placed in clean 1-L round plastic containers with leak-proof "snap-on" lids, then chilled on ice until returning to the field station. At the field station, sediment samples were stored frozen until they could be analyzed for particle size distribution. The particle size distribution was determined by sieving thawed samples through a series of standard sieves (mesh diameters of 31.5, 9.5, 2.0, 1.4, and 0.053 mm), then measuring the dry weights of each sediment fraction and the filtrate passing through the 0.053-mm sieve. For this study, sediment particles $\leq$0.053 mm are referred to as silt; >0.053-1.4 mm, as sand; >1.4-2.0 mm, as coarse sand; >2.0-9.5 mm, as gravel; >9.5 mm-31.5 mm, as pebble; and >31.5 mm, as cobble. Schoklitsch's sediment factor

(s) was calculated with a graphical procedure described by Bogardi (1974). By definition, s=a/b, where a is the area above the granulometric curve and b is the area below the granulometric curve. The granulometric curve for each sediment sample was drawn by plotting the maximum diameter of the sediment fractions (i.e., 0.053, 1.4, 2.0, 9.5, 31.5, and 64 mm) on the x-axis and the cumulative percentages of their dry weights on the y-axis. According to Bogardi (1974), the value for s (which can assume any arbitrary positive value) increases as sediment material becomes coarser.

Data Analysis

Chi-square (χ^2)analysis of fish counts was used to determine if the proportions of captured fishes differed between gear types (gill nets and minnow traps), between nearshore and offshore sites, and among sampling times (February/March, May, August, and November). Except as noted, analysis of variance (ANOVA) performed with logarithmically transformed data was used to determine if relative abundance of fish species (based on catch per unit effort) and selected environmental factors varied among sites. When F values from ANOVA were significant ($P \leq 0.05$), Tukey's studentized range test was used to compare geometric means for statistical differences.

Green and Vascotto (1978) recommended using cluster analysis to identify species-assemblage groups, followed by discriminant analysis to determine if the composition of species-assemblage groups is controlled by environmental factors. Cluster analysis was performed according to gear type (gill nets or minnow traps) by using the average numbers of individuals of each fish species captured during the study. "Significant" clusters were estimated by plotting cubic clustering criterion (CCC) values and pseudo t^2 statistic values (derived from the cluster analysis procedure) with their corresponding cluster numbers (SAS 1990). The significance of a cluster was determined by looking for a peak value in the CCC (the "significant number of clusters" is the number of clusters corresponding to the peak value) and by looking for a peak value in the pseudo t^2 statistic (the "significant number of clusters" is the number of clusters corresponding to the peak value plus one additional cluster).

With one exception, all statistical computations were conducted with SAS software for windows, version 7 (SAS Institute Inc., Cary, North Carolina). Computations for simple discriminant analysis were conducted with a BASIC program written by Ludwig and Reynolds (1988).

RESULTS

A total of 2,656 fish represented by 8 species from 7 families was captured during this study (Table 1). Gill nets accounted for seven species--Sacramento perch; largemouth bass, *Micropterus salmoides*; Pacific herring; prickly sculpin, *Cottus asper*; silver surfperch, *Hyperprosopon ellipticum*; longfin smelt; and striped bass--whereas minnow traps accounted for three species--Sacramento perch; prickly sculpin; and threespine stickleback, *Gasterosteus aculeatus*. Despite efforts to collect tidewater goby with minnow traps and, during August only, with about 20 undocumented

Table 1. List of fish species, number caught, and relative contribution (%) to the total catch for gill nets and minnow traps fished in Abbotts Lagoon during February/March, May, August, and November 1999.

				Gill nets		Minnow traps	
Family	Species	Common name	Code	No. fish	%	No. fish	%
Centrarchidae	*Archoplites interruptus*	Sacramento perch	SP	676	39.26	3	0.32
	Micropterus salmoides	Largemouth bass	LMB	35	2.03	0	0.00
Clupeidae	*Clupea pallasi*	Pacific herring	PH	1,005	58.36	0	0.00
Cottidae	*Cottus asper*	Prickly sculpin	PS	1	0.06	77	8.24
Embiotocidae	*Hyperprosopon ellipticum*	Silver surfperch	SSP	3	0.17	0	0.00
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback	TSS	0	0.00	854	91.43
Osmeridae	*Spirinchus thaleichthys*	Longfin smelt	LFS	1	0.06	0	0.00
Percichthyidae	*Morone saxatilis*	Striped bass	SB	1	0.06	0	0.00
Totals				1,722	100.00	934	99.99

shoreline hauls employing a 3.0-m X 1.2-m (3.2-mm square mesh) minnow seine, this species was neither observed nor captured in the lagoon.

Proportions (percentages) of captured fishes differed significantly between gear types (χ^2=2,639, df=7, P<0.0001). When catches with the two gears were compared, Sacramento perch and Pacific herring collectively accounted for over 97% of the gill net catch, whereas threespine stickleback accounted for over 91% of the minnow trap catch (Table 1).

Abundance and Distribution of Fishes, and Fish Species Assemblages

The most ubiquitous species captured by gill nets were Sacramento perch (13 of 14 sites) and Pacific herring (12 of 14 sites; Table 2). These two species were common in the lagoon as evidenced by their high contributions to the gill net catch (Table 1). Largemouth bass occurred at nine gill net sites, silver surfperch occurred at two gill net sites, and prickly sculpin, longfin smelt and striped bass each occurred at only one gill net site. Prickly sculpin was the most ubiquitous species captured in minnow traps (all seven sites), followed by threespine stickleback (four minnow trap sites), and Sacramento perch (one site; Table 2).

According to gill net catches, the proportions of fish species differed between nearshore and offshore sites (χ^2=92, df=5, P<0.0001). Pacific herring was more important at offshore sites (66%) than at nearshore sites (45%), whereas Sacramento perch was more important at nearshore sites (50%) than at offshore sites (34%). Largemouth bass was slightly more important at nearshore sites (5%) than at offshore sites (<1%).

The proportions of fish species captured by gill nets differed over time at both nearshore sites (χ^2=174, df=15, P<0.0001) and offshore sites (χ^2=446, df=6, P<0.0001). Sacramento perch predominated the gill net catch in February/March (nearshore, 76%; offshore, 98%) and in August (nearshore, 84%; offshore, 98%), whereas Pacific herring predominated the gill net catch in May (nearshore, 48%; offshore, 53%) and in November (nearshore, 72%; offshore, 87%).

The proportions of fish species captured by minnow traps at nearshore sites also differed over time (χ^2=447, df=6, P<0.0001). Prickly sculpin was the only species captured on all four sampling trips. Although the numbers of prickly sculpin captured during each time period did not vary widely (catches ranged from 11 fish in February/March to 36 fish in August), the contribution of this species to the overall catch exhibited considerable variation (4% in August to 100% in both May and November). Threespine stickleback was captured in February/March (3 fish accounted for 21% of the catch for all species combined) and August (851 fish accounted for 96% of the catch), whereas Sacramento perch was captured only in August (3 fish accounted for <1% of the catch).

According to Ward's minimum-variance method of cluster analysis, the 14 sites fished by gill nets and the seven sites fished by minnow traps can be divided into two major clusters (groups): one composed of sites in the upper and middle lagoons and the other composed of sites in the lower lagoon (Fig. 2). The existence of two clusters

Table 2. Relative abundance (number of fish/gill net or number of fish/five minnow traps) of fishes captured during overnight sets of gill nets and minnow traps from 14 sampling sites in Abbotts Lagoon on as many as four occasions during 1999. Values are geometric means for various fish species.[a,b]

Site[c] or	Gill net							Minnow trap		
ANOVA	SP	LMB	PH	PS	SSP	LFS	SB	SP	PS	TSS
UL1N	36.68 A	2.22	0.00 C	0.00	0.00	0.00	0.00	0.00	0.86	0.00
UL1O	36.44 A	0.41	0.00 C	0.19	0.00	0.00	0.00	---	---	---
ML1N	12.54 AB	1.24	0.78 BC	0.00	0.00	0.00	0.00	0.41	1.38	0.19
ML1O	11.19 ABC	0.41	0.78 BC	0.00	0.00	0.00	0.00	---	---	---
ML2N	11.16 ABC	0.41	0.73 BC	0.00	0.00	0.00	0.00	0.00	2.31	0.00
ML2O	10.19 ABCD	0.19	0.68 BC	0.00	0.00	0.00	0.00	---	---	---
ML3N	4.89 ABCD	1.00	2.87 ABC	0.00	0.00	0.00	0.00	0.00	1.78	0.00
ML3O	5.34 ABCD	0.00	2.58 ABC	0.00	0.00	0.00	0.00	---	---	---
LL1N	1.40 BD	0.19	8.30 ABC	0.00	0.19	0.00	0.00	0.00	0.86	4.62
LL1O[d]	1.45 BD	0.00	61.09 AB	0.00	0.73	0.00	0.00	---	---	---
LL2N	0.41 CD	0.00	9.80 ABC	0.00	0.00	0.00	0.00	0.00	2.28	1.99
LL2O[d]	0.73 BD	0.00	92.81 A	0.00	0.00	0.00	0.00	---	---	---
LL3N	0.32 D	0.19	13.21 ABC	0.00	0.00	0.19	0.19	0.00	2.08	4.36
LL3O[d]	0.00 BD	0.00	46.12 AB	0.00	0.00	0.00	0.00	---	---	---
F(df1,df2)[e,f]	6.94****	1.87	4.81****	0.85	1.89	0.85	0.85	1.00	0.36	0.86

[a]Within a column, geometric means followed by the same capital letter are not statistically different (P>0.05) according to Tukey's studentized range test.

[b]See Table 1 for names of fishes.

[c]See Figure 1 for general locations of sampling sites.

[d]Gill nets were fished only in May and November.

[e]For gill net catches, df1=13, df2=49; for minnow trap catches, df1=6, df2=27.

[f]Codes: ****, P<0.0005.

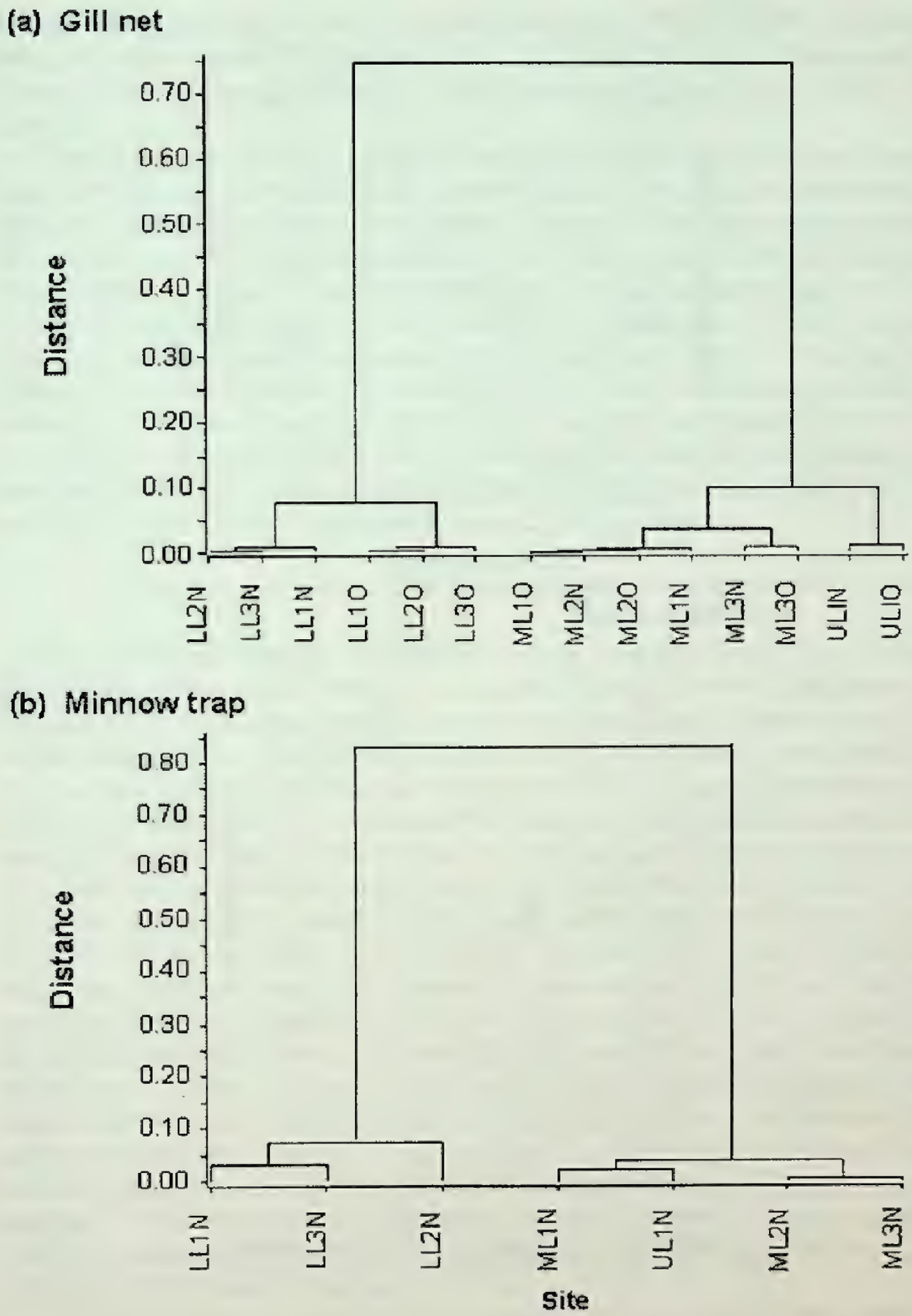

Figure 2. Dendrograms for cluster analysis (Ward's minimum-variance method) based on (a) gillnet catch statistics from 14 sampling sites and (b) minnow trap catch statistics from seven sampling sites. See Figure 1 for general locations of sampling sites.

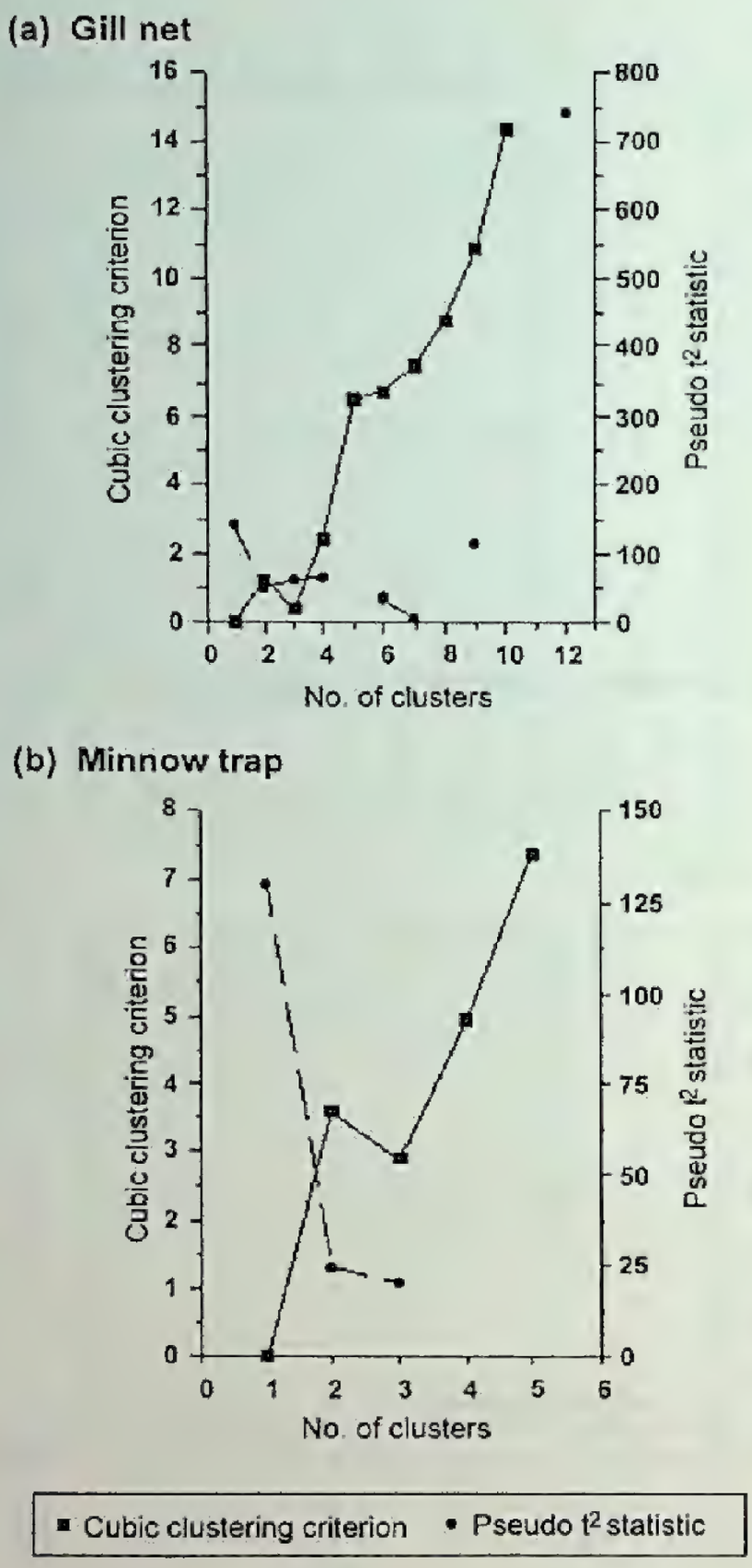

Figure 3. Plots of cubic clustering criterion (CCC) values and pseudo t^2 statistic values in relation to number of clusters for (a) gillnet catches and (b) minnow trap catches. For CCC values, the "significant number of clusters" is the number of clusters corresponding to the peak value. For pseudo t^2 statistic values, the "significant number of clusters" is the number of clusters corresponding to the peak value plus one additional cluster.

is observed in plots of CCC values and pseudo t^2 statistic values (Fig. 3). For both gill nets and minnow traps, CCC values show a peak at two clusters and a drop at three clusters, whereas pseudo t^2 statistics show a peak at one cluster and a drop at two clusters.

Although considerable overlap in fish species occurred within the two groups of sites, inspection of relative abundance patterns from gill net catches showed that the upper and middle lagoon sites were populated mostly by Sacramento perch whereas the lower lagoon sites were populated mostly by Pacific herring (Table 2). In addition, largemouth bass was more numerous and widely distributed in the upper and middle lagoons than in the lower lagoon. On the other hand, three species (silver surfperch, longfin smelt, and striped bass) were seemingly restricted to sites in the lower lagoon. Minnow trap catches also demonstrated differences in the relative abundance of fishes inhabiting sites in the upper and middle lagoons and the lower lagoon (Table 2). For example, threespine stickleback was not captured in the upper lagoon, and only a few individuals were captured in the middle lagoon. By comparison, stickleback was caught in large numbers in the lower lagoon, especially during August.

Water Quality and Other Environmental Characteristics

Environmental conditions at Abbotts Lagoon varied markedly from February/March to November. Runoff from rainstorms created very high water conditions during February/March when broad strips of open water connected the upper lagoon to the middle lagoon and the middle lagoon to the lower lagoon. According to a local observer (C.R. Kratzer, U.S. Geological Survey, Sacramento, California, unpublished observations), the sandbar in the lower lagoon was briefly breached at the end of March, resulting in an open connection to the Pacific Ocean for about one week. Following closure of the breach, water levels in the lagoon began to recede, and had dropped 2-3 meters by May. Moreover, the three sections of the lagoon (upper, middle, and lower lagoons) were now connected by narrow strips of water, including a small (1.5-m high) waterfall or cascading rapids that flowed from the middle lagoon into the lower lagoon. The eastern shoreline of the lower lagoon, which had consisted of rocky dropoffs or small cliffs during high water in February, was transformed into several small cobblestone beaches in May as the water level receded. By August, water levels had dropped another 2-3 meters and the upper and middle lagoons were connected by a very narrow strip of shallow (<6 cm) water. Moreover, the waterfall separating the middle and lower lagoons was flowing at just a trickle (discharge visually estimated at <0.1 m^3/sec). Beaches along the eastern shore of the lower lagoon were also more exposed, with gravel and sand now predominant over cobble. These low-water conditions persisted into November, with water levels dropping another 0.5-1.0 m.

With three exceptions (salinity, total ammonia, and water depth), water quality and other environmental variables measured during this study did not vary significantly ($P>0.05$) among sites (Table 3). Water temperature averaged 14.9-15.7°C, dissolved oxygen concentrations averaged 7.0-8.8 mg/L, pH averaged 6.7-7.6, and turbidity averaged 4.4-10.7 nephelometric units (NTUs). By comparison, a gradient existed for

Table 3. Water temperature, dissolved oxygen, pH, salinity, total ammonia (NH_3+NH_4^+), turbidity, and water depth at 14 sites in Abbotts Lagoon during 1999. Values are geometric means (ranges in parentheses).[a,b]

Site[c] or ANOVA	Temperature (°C)	Dissolved oxygen (mg/L)	pH	Salinity (‰)	Total ammonia (mg/L)	Turbidity (NTUs)	Water depth (m)
UL1N	15.6 (10.7-21.9)	7.0 (5.0-10.8)	6.9 (4.6-9.0)	0.2 (0.1-0.2) B	0.20 (0.09-0.42)	9.6 (1.1-46.4)	1.8 (1.5-2.8) D
UL1O	15.5 (9.8-22.1)	7.2 (4.2-10.9)	7.1 (4.5-9.1)	0.2 (0.1-0.2) B	0.21 (0.08-0.42)	10.7 (2.0-70.2)	2.1 (1.6-3.1) CD
ML1N	15.7 (10.8-20.6)	7.9 (5.6-9.7)	7.2 (5.4-8.6)	0.5 (0.2-0.8) B	0.12 (0.06-0.18)	6.9 (0.8-19.3)	3.3 (1.8-5.5)ABCD
ML1O	15.6 (10.9-20.6)	7.7 (6.0-9.1)	7.2 (5.7-8.6)	0.5 (0.2-0.8) B	0.12 (0.07-0.18)	6.5 (0.8-29.9)	3.8 (2.6-5.8) ABCD
ML2N	15.5 (10.3-20.6)	8.1 (6.9-9.1)	7.2 (5.6-8.7)	0.5 (0.2-0.8) B	0.11 (0.07-0.17)	7.6 (1.4-17.1)	3.0 (1.3-4.9) BCD
ML2O	15.5 (10.8-20.6)	7.8 (7.0-8.6)	7.2 (5.5-8.7)	0.5 (0.2-0.8) B	0.11 (0.06-0.21)	7.8 (3.2-17.1)	5.1 (4.1-6.5) ABC
ML3N	15.4 (10.8-20.7)	8.0 (7.0-8.7)	7.2 (5.4-9.0)	0.5 (0.2-0.8) B	0.11 (0.07-0.22)	8.8 (2.9-16.2)	3.8 (1.0-6.5) ABCD
ML3O	15.3 (10.9-20.7)	7.8 (6.4-9.2)	7.3 (5.4-9.0)	0.5 (0.2-0.8) B	0.10 (0.07-0.19)	7.4 (3.9-16.2)	5.9 (3.7-7.5) AB
LL1N	15.3 (12.0-19.6)	8.6 (7.5-9.6)	7.5 (5.9-9.0)	4.7 (2.7-6.1) A	0.09 (0.08-0.12)	4.4 (1.3-37.2)	4.1 (2.5-6.3) ABCD
LL1O	14.9 (14.4-15.6)	8.3 (7.5-10.0)	6.7 (5.7-7.8)	5.4 (4.8-6.1) A	0.06 (0.06-0.07)	5.3 (1.9-91.4)	8.3 (6.1-8.8) AB
LL2N	15.4 (12.1-19.4)	8.8 (7.6-11.0)	7.6 (6.0-8.9)	4.8 (3.1-6.2) A	0.07 (0.06-0.08)	6.8 (1.3-14.2)	3.2 (2.3-4.4) ABCD
LL2O	14.9 (14.5-15.7)	8.3 (7.5-9.9)	6.9 (5.8-7.9)	5.4 (4.7-6.1) A	0.06 (0.06-0.06)	6.3 (2.5-12.3)	9.6 (9.5-10.0) A
LL3N	15.1 (12.0-19.4)	8.5 (7.5-9.6)	7.4 (5.8-8.8)	4.8 (3.3-6.1) A	0.08 (0.06-0.11)	5.2 (0.6-30.4)	4.0 (1.9-6.6) ABCD
LL3O	15.0 (14.5-15.9)	8.3 (7.6-9.7)	6.8 (5.8-7.8)	5.4 (4.7-6.1) A	0.06 (0.05-0.08)	6.0 (2.6-10.0)	6.2 (5.5-7.2) ABC
$F_{13,36}$[d]	0.02	1.42	0.11	27.22***	2.46*	0.47	4.98***

[a]Measurements of water temperature, dissolved oxygen, pH, salinity, and turbidity came from vertical profiles of the uppermost 3-m of the water column, whereas measurements of total ammonia came from 15-cm beneath the water surface.

[b]Within a column, geometric means followed by the same capital letter are not significantly different ($P>0.05$) according to Tukey's studentized range test.

[c]See Figure 1 for general locations of sampling sites.

[d]Codes: *, $P\leq0.05$; ***, $P\leq0.0001$.

salinity, with brackish conditions occurring in the lower lagoon and much fresher conditions occurring in the middle and upper lagoons. Although one-way ANOVA indicated that total ammonia concentrations varied significantly among sites, none of the between-site comparisons were significant according to Tukey's studentized range test. Nevertheless, mean values for total ammonia were highest at sites in the upper lagoon (0.20-0.21 mg/L), intermediate at sites in the middle lagoon (0.10-0.12 mg/L), and lowest at sites in the lower lagoon (0.06-0.09 mg/L). Water depth also exhibited a longitudinal gradient, with the deepest water occurring in the lower lagoon, followed by the middle lagoon, and relatively shallow water occurring in the upper lagoon.

Overall, a mixture of sand and silt predominated the bottom substrates at most sites in Abbotts Lagoon (Table 4). Although the particle size distribution of sediment samples did not differ significantly among sites, relatively coarse sediments occurred at some shoreline sites (especially in the lower lagoon) whereas finer-grained sediments occurred at offshore sites and in the upper lagoon.

Relation Between Species Assemblages and Environmental Variables

According to simple discriminant analysis, significant differences existed among the abiotic characteristics of the two groups of sites classified by cluster analysis (Fig. 4). The multivariate distance (Mahalanobis D^2 statistic, 8,198) separating the two groups was significant ($F_{8,5}$=1,464, P<0.0001). Moreover, all 14 sites were correctly grouped according to whether they contained a species assemblage predominated by Sacramento perch and largemouth bass (centroid=16,102) or by Pacific herring and threespine stickleback (centroid=7,917). Salinity contributed the most towards the total multivariate distance (107.8%), followed by temperature (0.9%), and Schoklitsch's sediment factor (0.3%). Turbidity was a neutral factor (0.0%), whereas pH (-0.3%), water depth (-1.0%), dissolved oxygen (-1.5%), and total ammonia (-6.1%) weakened the analysis.

DISCUSSION

Although historical data on composition and relative abundance of fishes in Abbotts Lagoon are almost nonexistent, available evidence suggests that few fish species have successfully colonized this water body. In a survey conducted during 1984, Self and Ranlett[1] (1984) documented the presence of six species in the lagoon--Sacramento perch, Pacific herring, staghorn sculpin, an unspecified "anchovy" presumed to be northern anchovy (*Engraulis mordax*, the only anchovy species with a geographic range that includes northern California; Miller and Lea 1972), striped bass, and starry flounder. By comparison, our study yielded eight species among the 2,656 fish captured from 14 sites over four separate time periods. These species consisted of Sacramento perch, largemouth bass, Pacific herring, prickly sculpin, threespine stickleback, silver surfperch, longfin smelt, and striped bass.

Cluster analysis indicated that the 14 sampling sites could be classified into two groups sharing several fish species that differed markedly in relative abundance. The

Table 4. Sediment particle size distribution and Schoklitsch's sediment factor (*s*) for samples collected during February/ March, May, August, and November 1999. Values for cobble, pebble, gravel, coarse sand, fine sand, and silt are arithmetic means, whereas values for *s* are geometric means.

Site[a] or ANOVA	Cobble (%)	Pebble (%)	Gravel (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	*s*
UL1N	---	---	---	---	64.22	35.78	0.00810
UL1O	---	---	---	---	63.56	36.44	0.00811
ML1N	---	---	0.09	0.30	93.89	5.72	0.01169
ML1O	---	---	0.06	0.73	82.83	16.38	0.01108
ML2N	---	0.09	0.26	0.26	92.59	6.79	0.01573
ML2O	---	---	0.39	11.37	60.56	27.69	0.01017
ML3N	---	---	0.96	11.51	63.86	23.67	0.01243
ML3O	---	---	0.09	2.64	81.55	15.72	0.01127
LL1N	24.56	0.38	0.35	0.17	71.40	3.14	0.05653
LL1O[b]	---	---	---	0.28	59.41	40.31	0.00788
LL2N	---	3.93	0.36	0.35	76.07	19.31	0.01412
LL2O[b]	---	---	---	0.20	63.71	36.10	0.00841
LL3N	14.84	11.30	1.12	0.39	70.08	2.26	0.07551
LL3O[b]	---	---	0.01	0.03	98.30	1.66	0.01301
$F_{13,49}$	NC[c]	NC[c]	NC[c]	NC[c]	NC[c]	NC[c]	1.61

[a]See Figure 1 for general locations of sampling sites.
[b]Means were computed from samples collected on two occasions (May and November 1999).
[c]Not computed.

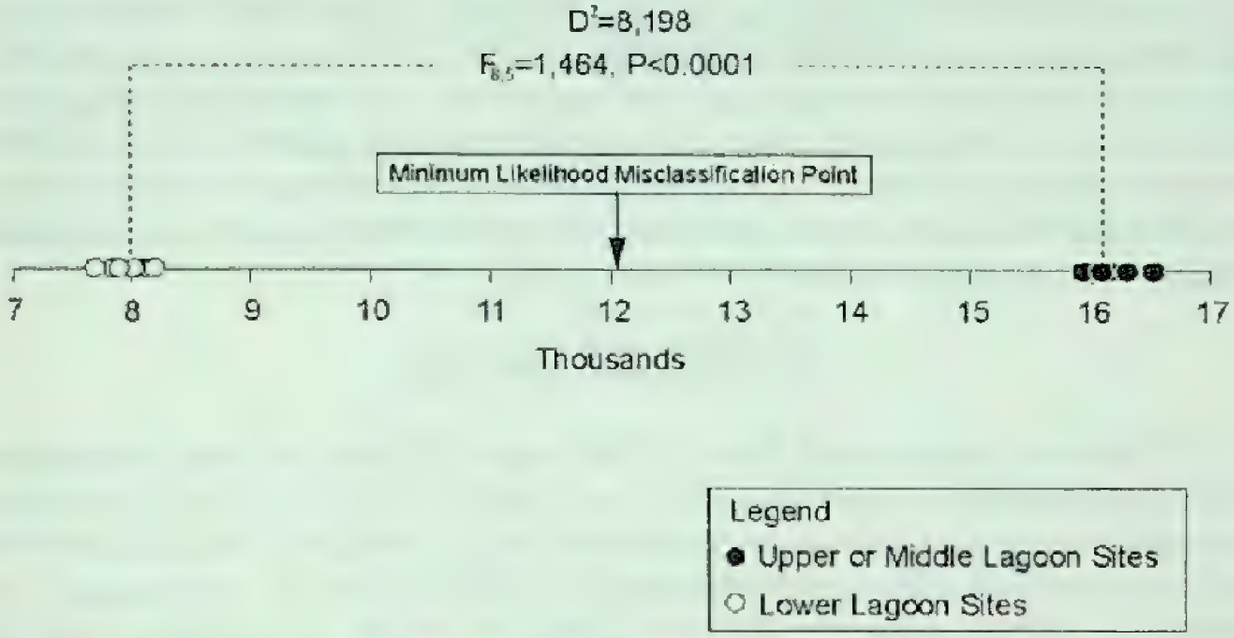

Figure 4. Simple discriminant analysis (SDA) for two groups of sampling sites (fish species assemblages) identified by cluster analysis. The SDA was conducted with the following environmental variables: water temperature, dissolved oxygen, pH, total ammonia, salinity, turbidity, water depth, and sediment particle size distribution. Eight sites in the upper and middle lagoons were correctly classified as containing a species assemblage dominated by Sacramento perch and largemouth bass, whereas six sites in the lower lagoon were correctly classified as containing a species assemblage dominated by Pacific herring and threespine stickleback.

first group of sites, which occurred in the upper and middle lagoons, was characterized by an abundance of Sacramento perch and, to a much lesser extent, largemouth bass. Pacific herring was also common at two sites in the middle lagoon, but this species was not captured in the upper lagoon. The second group of sites, which was confined to the lower lagoon, was characterized by an abundance of Pacific herring and threespine stickleback. Although Sacramento perch and largemouth bass occurred in the lower lagoon, they were few in number and exhibited a seemingly uneven distribution pattern.

According to simple discriminant analysis, the two groups of sites were differentiated almost exclusively by salinity. In other words, high numbers of Sacramento perch and largemouth bass occurred mostly in freshwater whereas high numbers of Pacific herring and threespine stickleback occurred mostly in brackish water. Although these findings seemingly support the generally accepted view that fish species assemblages in estuarine habitats are structured primarily by the physiological tolerance of individual species to salinity (e.g., Day et al. 1989, Moyle and Cech 1996), several species inhabiting Abbotts Lagoon can tolerate a relatively broad range of dissolved salt concentrations. For example, McCarraher and Gregory (1970) reported that Sacramento perch, which typically inhabits freshwater habitats within its native range, can survive and reproduce in chloride-sulfate waters with salinities as high as 17,000 mg/L. Moreover, the Pacific herring is a marine species that occasionally wanders into freshwater when it moves into estuaries to spawn (Moyle 1976), whereas the threespine

stickleback is represented by marine, anadromous, and freshwater populations in California (Moyle 1976, Eschmeyer and Herald 1983). Although beyond the scope of this study, a host of unmeasured ecological factors (e.g., fish-forage supply, potential predators) could also be responsible for structuring fish species assemblages in Abbotts Lagoon, particularly if the ecological factors vary in relation to the salinity gradient. Investigations on the trophic ecology of Sacramento perch and Pacific herring would help to determine if food supply and predation are important determinants of spatial patterns exhibited by these two species.

ACKNOWLEDGMENTS

We thank the National Park Service (Point Reyes National Seashore) for logistical support and access to the study area; C.R. Kratzer and W. Shook for helpful discussions related to design and implementation of the study; K.R. English for assisting with field and laboratory work, and creating the computerized datasets; and B. Ketcham and C.R. Kratzer for reviewing an early draft of the report. This study was funded primarily by the U.S. Geological Survey, Water Resources Division, under a competitive grant from the NPS-USGS Water-Quality Monitoring and Assessment Partnership.

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Received: 24 January 2001
Accepted: 18 June 2002

Calif. Fish and Game 87(4):139-152 2001

ANALYSIS OF MATURITY IN LINGCOD, *OPHIODON ELONGATUS*

KELLY R. SILBERBERG, THOMAS E. LAIDIG,
PETER B. ADAMS
National Marine Fisheries Service
Southwest Fisheries Science Center
Santa Cruz Laboratory
110 Shaffer Rd
Santa Cruz, California 95060

and

DOUGLAS ALBIN
California Department of Fish and Game
19160 South Harbor Drive
Fort Bragg, California 95437

Lingcod, *Ophiodon elongatus*, maturity data from northern and central California commercial catch samples were analyzed to determine maturity patterns including length and age at 50% maturity and seasonal patterns in maturation of gonads. Female lingcod attained 50% maturity at 557 mm fork length (FL) and 3.8 years. Males attained 50% maturity at 461 mm FL and 3.2 years. Females matured over a range from 437-725 mm FL and 2-8 years of age, while males matured over a range from 390-664 mm FL and 2-7 years. The abundance of females with mature ovaries began to increase in October, prior to the spawning period, peaked in January, then declined through February. Spent females were most abundant during February and March, directly following the peak spawning period. Ripe males began to appear in September and increased in abundance through March.

INTRODUCTION

Lingcod, *Ophiodon elongatus*, off Washington, Oregon, and California have declined to less than 20% of the numbers considered needed for equilibrium populations (Jagielo et al. 1997[1], Adams et al. 1999[2]). This development calls for immediate action

[1]Jagielo, T., P. Adams, M. Peoples, S. Rosenfield, K. Silberberg, and T. Laidig. 1997. Assessment of lingcod in 1997. *In* Pacific Fishery Management Council. 1997. Appendix: Status of the Pacific coast groundfish fishery through 1997 and recommended acceptable biological catches for 1998: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

[2]Adams, P.B., E.H. Williams, K.R. Silberberg, and T.E. Laidig. 1999. Southern lingcod stock assessment in 1999. *In* Pacific Fishery Management Council. 1999. Appendix: Status of the Pacific coast groundfish fishery through 1999 and recommended acceptable biological catches for 2000: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, OR 97201.

by resource managers. Lingcod management has been based on limiting the catch to individuals above a set minimum size, a method widely used to protect the reproductive potential of fish populations (Karpov et al. 1995). The first established California size limit for lingcod was 22 in. (which corresponds to 548 mm FL [Laidig et al. 1997]) for sport caught fish in 1981. In 1995, this limit was applied to the commercial fisheries as well (Jagielo et al. 1997[1]). As the abundance of lingcod continued to decline, size limits were increased to 24 inches (in 1998), and 26 inches (in 2001) for both sport and commercial fisheries.

Size limits are commonly based on length at 50% maturity. This allows managers to set a size limit at which theoretically 50% of the population should reach sexual maturity, and, therefore, have the ability to reproduce. The size limits used for lingcod in California, however, were based on studies using outmoded methods of age determination (surface aging of vertebrae and otoliths) for lingcod and small sample sizes (e.g., Phillips 1959, Miller and Geibel 1973). To strengthen the basis for a given minimum size limit, the current study examined the maturity of large samples of lingcod from northern and central California using the most recently developed methods to determine age.

METHODS

Data collection began in March 1994 and continued through December 1997. Fish were collected from the commercial bottom trawl and hook and line fisheries. Although samples from 1995-1997 were subject to a 22-in total length size limit (Jagielo et al. 1997[1]), a small percentage of undersized fish were included in landings, allowing for the collection of immature fish of both sexes. The sampling area was confined to northern and central California and ranged from Crescent City to Morro Bay. Random 50-lb batches of lingcod were sampled at dockside. Up to four batches were sampled for each trip per vessel. Data collection for each fish consisted of determining gonad maturity stage, sex, fork length (FL) and, when possible, removal of the dorsal fin rays for age determination.

Stage at maturity was determined by visual observation of the gonads. Five different stages (immature, maturing, mature, spent, and transitional) were used for assessing female maturity and three stages (immature, transitional, and ripe) for males. The maturity stages used were defined by the Washington Department of Fish and Wildlife (WDFW) for male and female lingcod (Table 1). All samplers were trained in the identification of the different maturity stages to reduce error. Female and male lingcod were considered mature if they fell into any of the WDFW stages other than immature. Immature female ovaries were characterized by small size, translucent pink to red color, and no distinguishable eggs present. Immature male testes were characterized by small size, round to thin ribbon shape, and a color ranging from translucent to white.

Ages were determined by examining annuli from cross-sections of dorsal fin rays using the methods described by Laidig et al. (2001). Length classes of 20 mm were used for the purposes of determining length at 50% maturity and percentages of immature

and mature fish within different length classes. Length and age at 50% maturity were determined for all samples combined and for just those collected between the months of November through February. Length and age at 50% maturity were estimated using the following logistic equation:

$$P = \frac{1}{1 + e^{-a(f-b)}}$$

where P = proportion mature at length or age x;
a,b = model parameters to be estimated; and
f = fork length (mm) or age (years).

Table 1. Lingcod, *Ophiodon elongatus*, maturity stages as defined by the Washington Department of Fish and Wildlife.

	Stages	Descriptions
Female	Immature	Ovaries are small (1.5-2.0 cm). Color ranges from translucent pink to red. Multiple-veined in appearance. No distinguishable eggs present.
	Maturing	Eggs are visible and opaque. Ovaries are swelling with an orange colored egg mass. The ovary wall may or may not be thickened.
	Mature	Ovaries are swollen with a large, pale, sticky egg mass. The ovaries will appear thickened.
	Spent	Thick-walled ovaries are empty and flaccid. They may appear bloodshot. There may be residual eggs inside the ovary.
	Transitional	Ovaries are thick-walled and firming in early stage, progressing to a thinner-walled, multi-veined condition similar to advanced immature ovaries. Eggs are not distinguishable.
Male	Immature	Testes are small, round to a thin ribbon in shape. Color may range from translucent to white.
	Transitional	Moderate sized testes, firm and compact. The color ranges from brown to mottled white. Flowing sperm is not present.
	Ripe	Testes moderate to large, softening and white. Flowing sperm should be detectable by pressure or visible in cut cross-section.

RESULTS

Sample Information

Data are from 1,899 lingcod (all but 50 fish sampled from the commercial bottom trawl fishery), with females accounting for 67% and males 33%. Samples were collected

throughout each year with the main concentration in summer and fall corresponding to the times of increased fishing pressure (Fig. 1). Females ranged from 361-1150 mm in length, and from 1-19 years in age, while males ranged from 360-855 mm, and from 2-13 years. No year or seasonal effects were determined, so data from all years were combined.

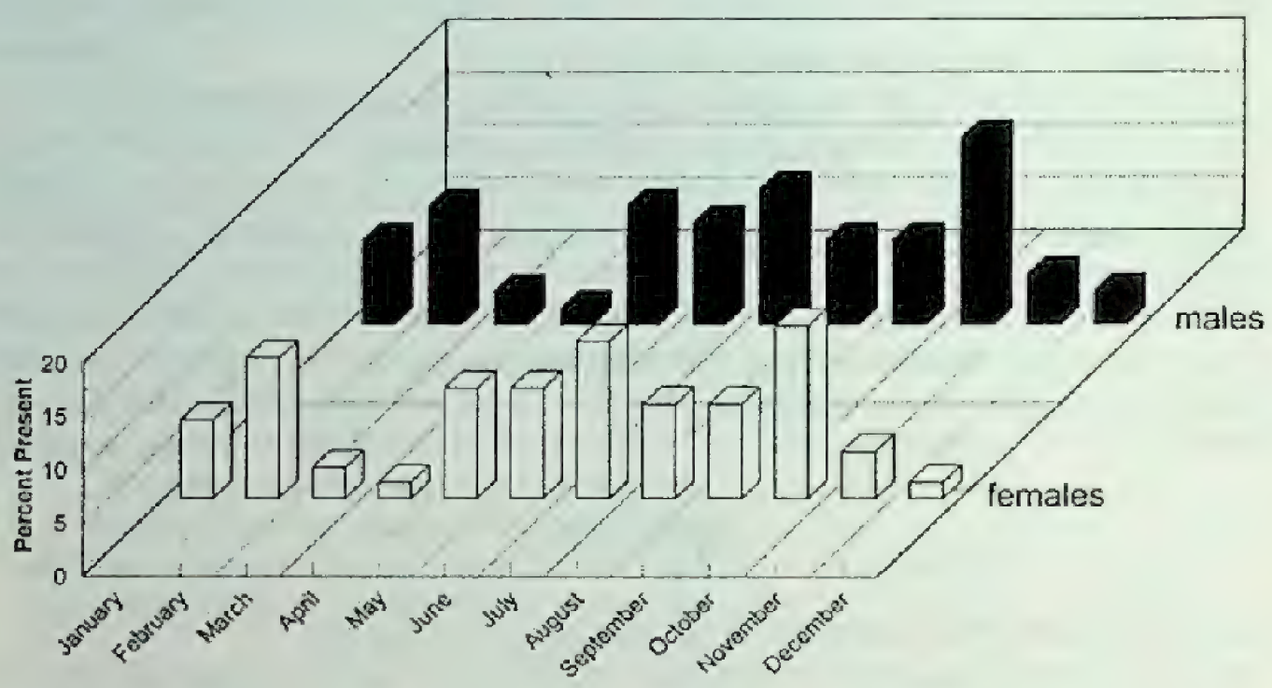

Figure 1. Percent occurrence of male and female lingcod, *Ophiodon elongatus*, samples by month in port samples collected from northern and central California, 1994-1997.

Length at Maturity

Females mature at a greater length than males. The smallest mature female was 437 mm, while the largest immature female was 725 mm (Fig. 2). The female length at maturity relationship increased from an estimated 10% maturity at 452 mm to 50% maturity at 557 mm and to 90% maturity at 661 mm (Fig. 3, parameters given in Table 2). In comparison, the smallest mature male was 390 mm, while the largest immature male was 664 mm (Fig. 4). The male length at maturity relationship increased from an estimated 10% maturity at 324 mm to 50% maturity at 461 mm and to 90% maturity at 598 mm (Fig. 5, parameters given in Table 2). Females reached 100% maturity at approximately 750 mm, while males reached 100% maturity at around 690 mm. The length at 50% maturity for samples collected between the months of November through February was 591 mm for females and 442 mm for males.

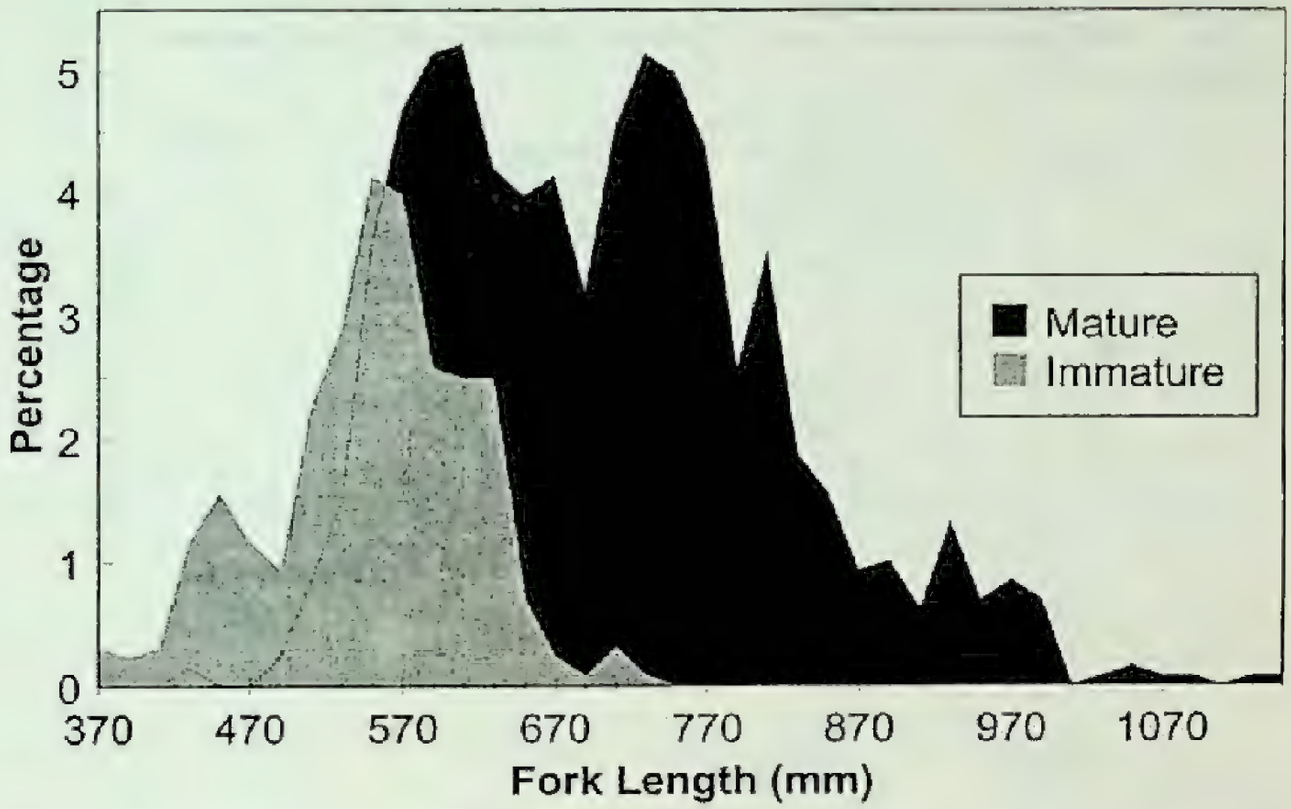

Figure 2. Percentage of immature (n=358) and mature (n=926) female lingcod, *Ophiodon elongatus*, by 20-mm length class from northern and central California, 1994-1997.

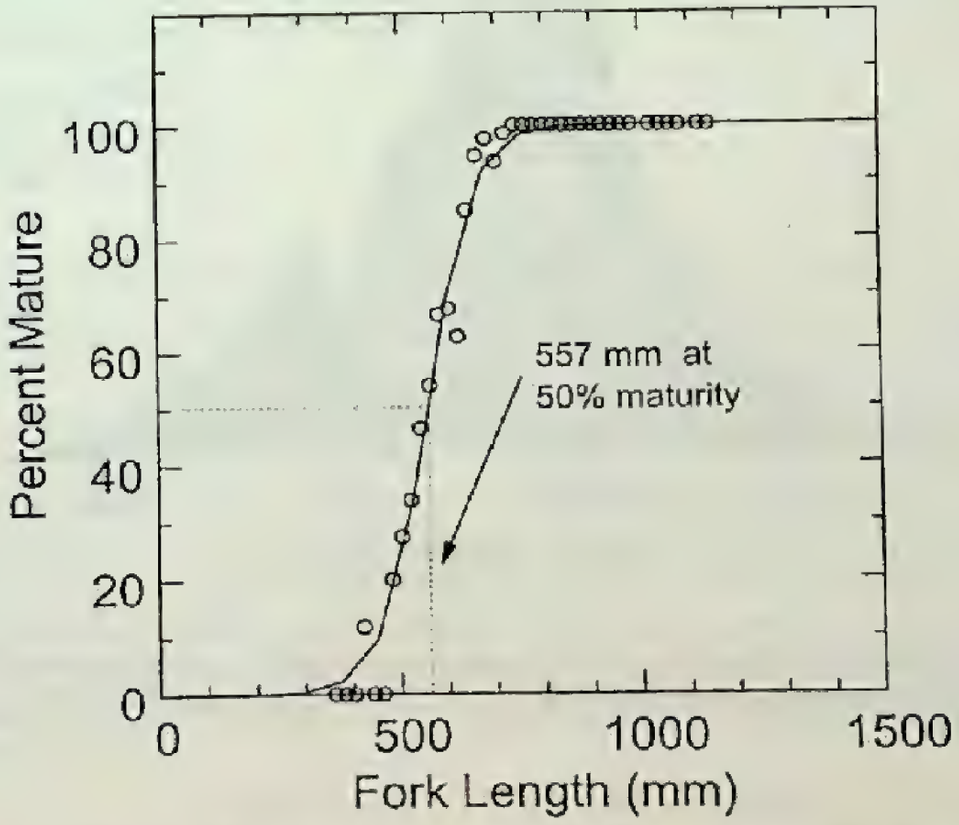

Figure 3. Length at maturity for female lingcod, *Ophiodon elongatus*, (n=1,284) by 20-mm length class from northern and central California, 1994-1997. Circles = actual values; solid line = estimated values; dashed line = length at 50% maturity.

Table 2. Model parameters for lingcod, *Ophiodon elongatus*, fork length and age at 50% maturity estimates.

Length	Female	Male
a	0.021	0.016
b	557.318	461.109
R^2	0.994	0.984
Age		
a	1.129	1.240
b	3.814	3.233
R^2	0.994	0.989

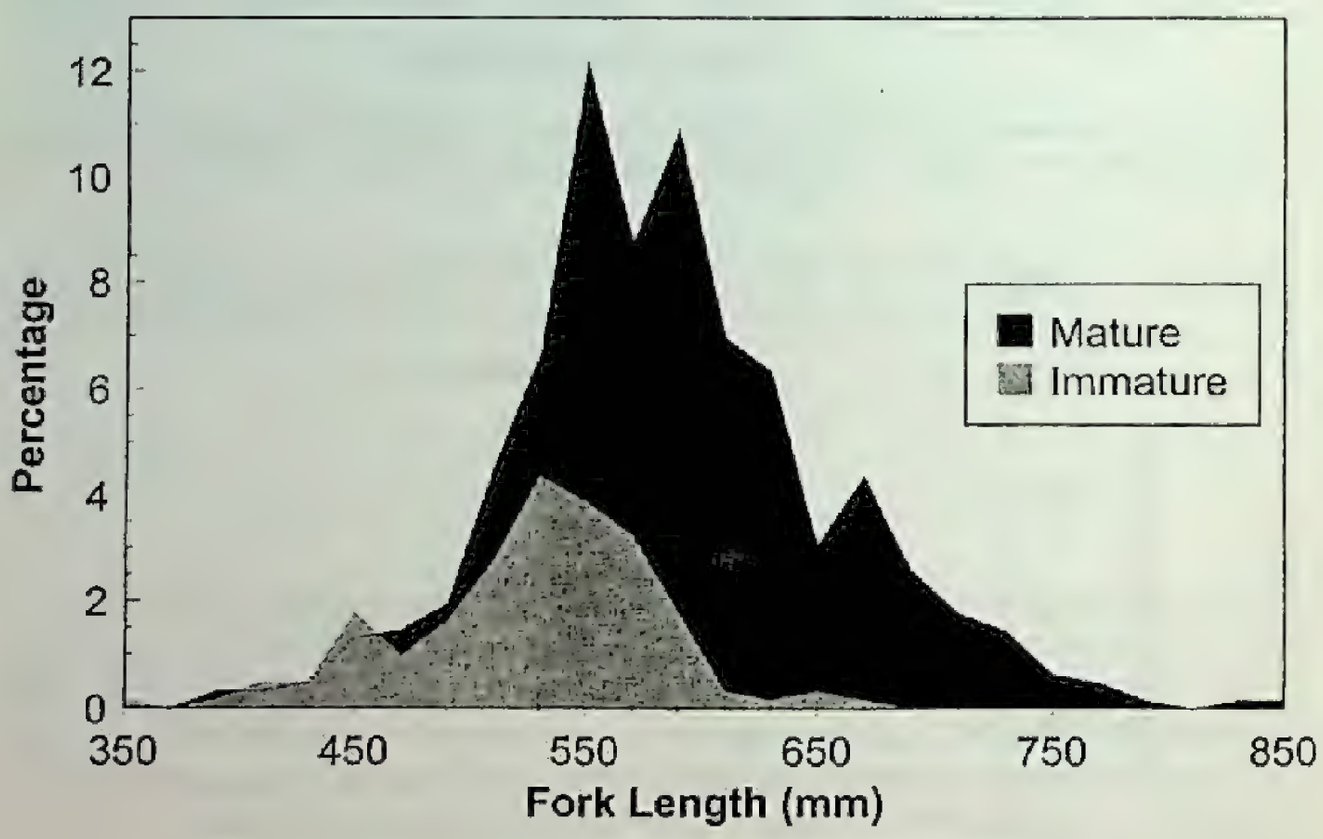

Figure 4. Percentage of immature (n=140) and mature (n=475) male lingcod, *Ophiodon elongatus*, by 20-mm length class from northern and central California, 1994-1997.

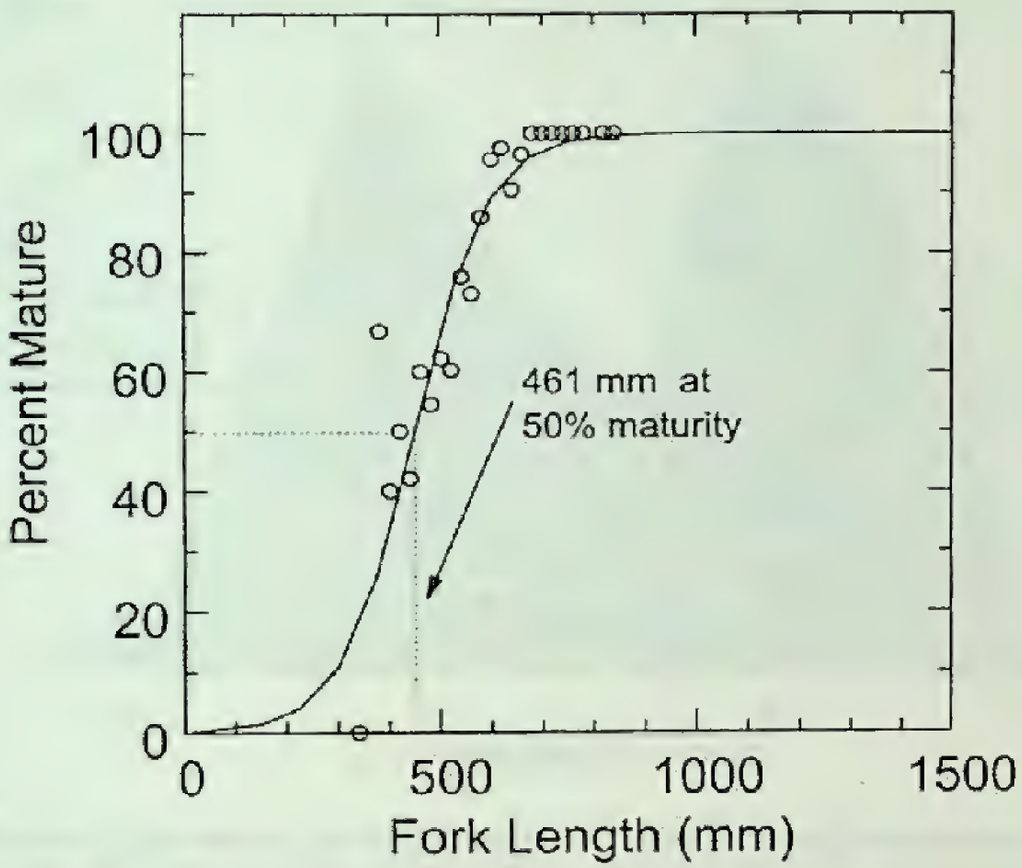

Figure 5. Length at maturity for male lingcod, *Ophiodon elongatus*, (n=615) by 20-mm length class from northern and central California, 1994-1997. Circles = actual values; solid line = estimated values; dashed line = length at 50% maturity.

Age at Maturity

There was less difference between female and male age at maturity than length at maturity, although females matured at slightly greater ages than males. The youngest mature female was two years old, while the oldest immature female was eight years old (Fig. 6). The age at 50% maturity was 3.8 years for females (Fig. 7, parameters given in Table 2). The youngest mature male was two years old and the oldest immature male was seven years old (Fig. 8). The age at 50% maturity was 3.2 years for males (Fig. 9, parameters given in Table 2). Between the ages of three years and eight years, there was a higher proportion of mature males than females. Females reached 100% maturity at nine years of age, while males reached 100% maturity a year younger, at eight years of age. For specimens collected between the months of November through February, the age at 50% maturity was 4.3 years for females and 2.9 years for males.

Seasonality in gonad maturity stage

Mature-stage ovaries began to appear in June, but the percentage of fish observed with mature ovaries increased markedly beginning in October, peaking in January, then

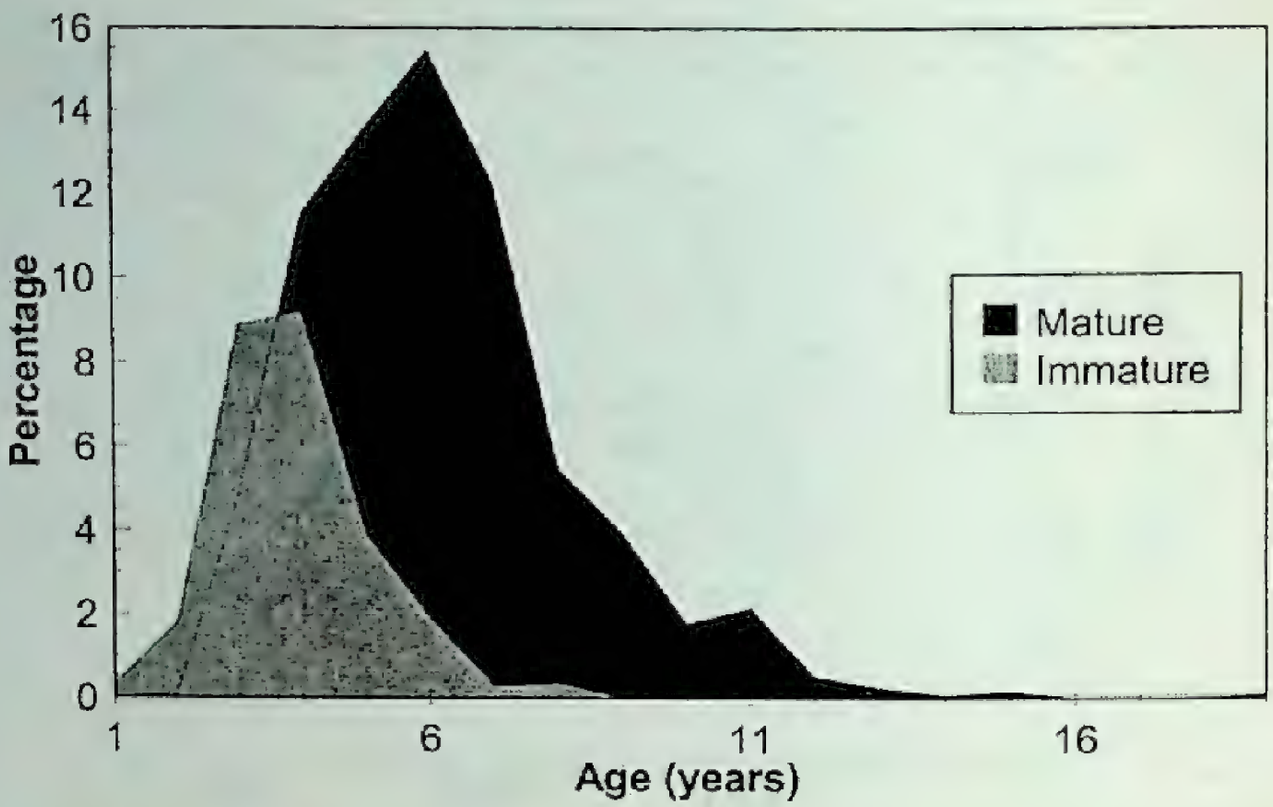

Figure 6. Percentage of immature (n=307) and mature (n=805) female lingcod, *Ophiodon elongatus*, by age from northern and central California, 1994-1997.

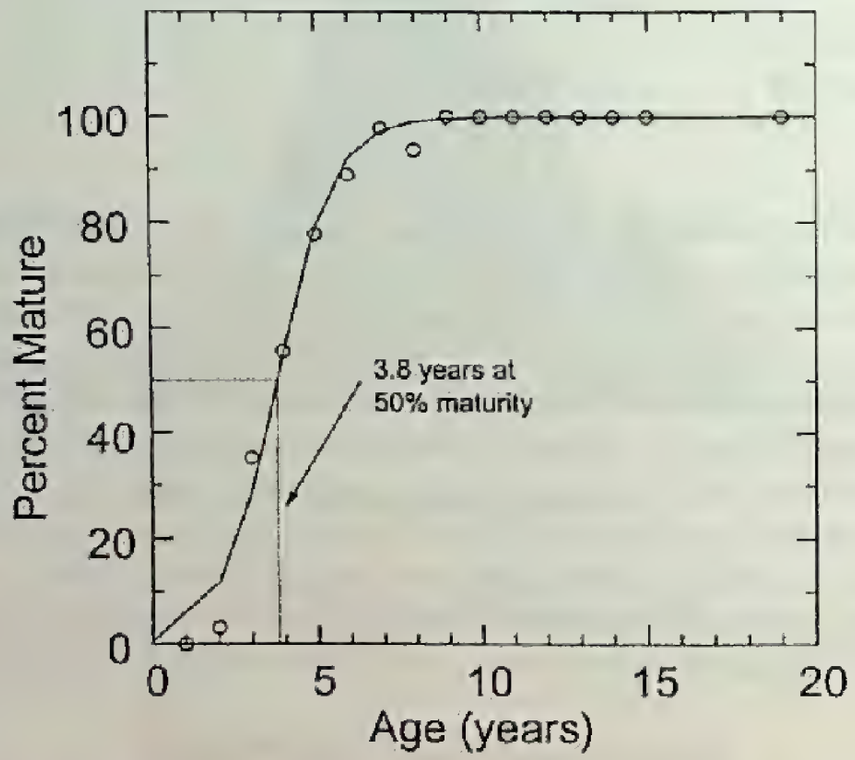

Figure 7. Age at maturity for female lingcod, *Ophiodon elongatus*, (n=1,112) from northern and central California, 1994-1997. Circles = actual values; solid line = estimated values; dashed line = age at 50% maturity.

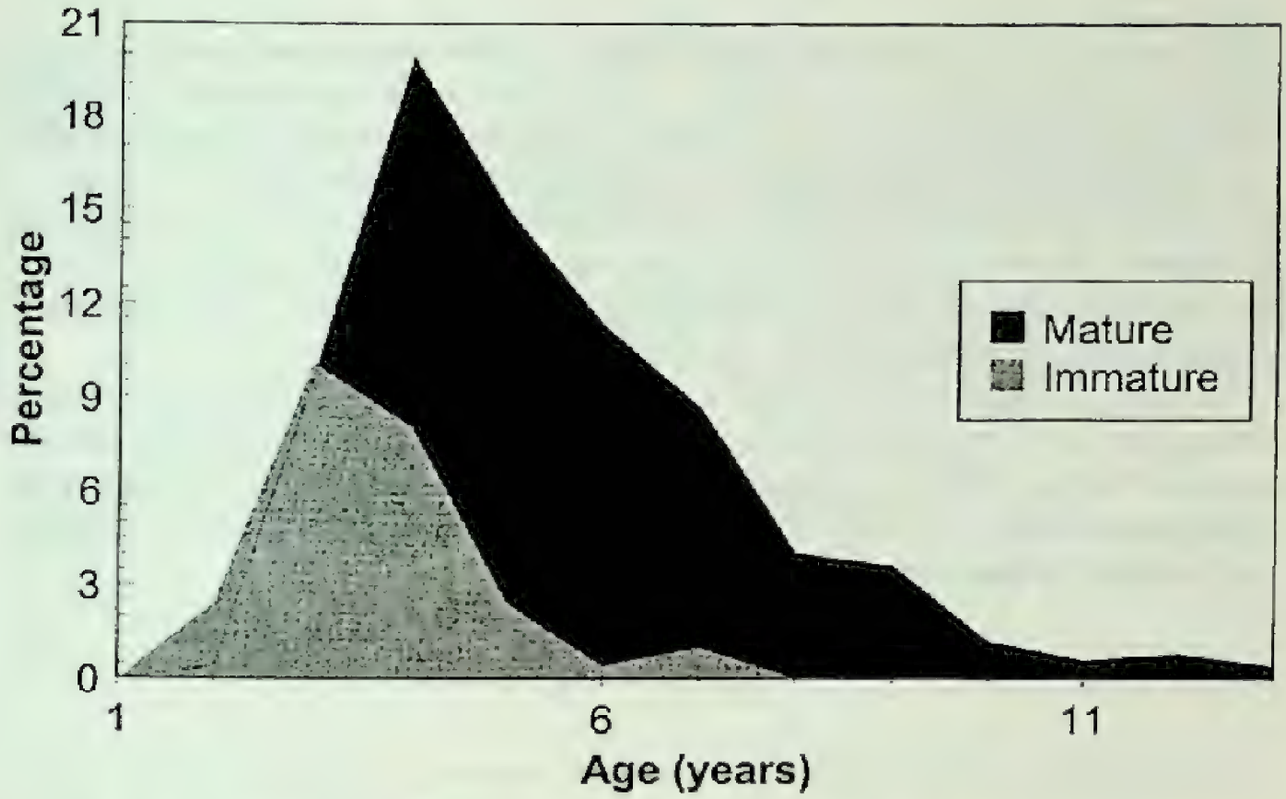

Figure 8. Percentage of immature (n=121) and mature (n=376) male lingcod , *Ophiodon elongatus*, by age from northern and central California, 1994-1997.

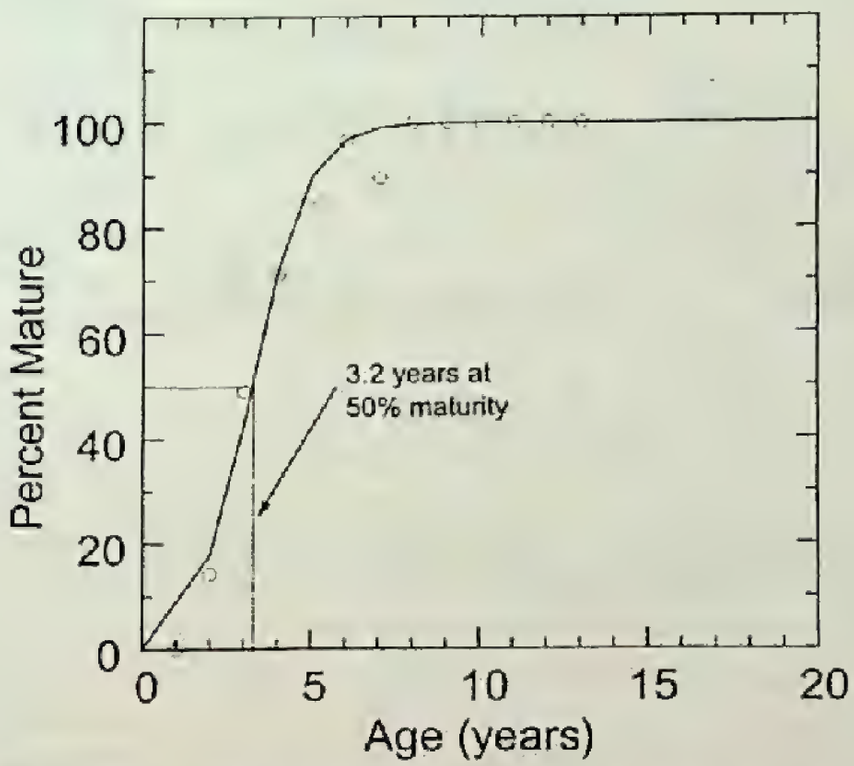

Figure 9. Age at maturity for male lingcod, *Ophiodon elongatus*, (n=497) from northern and central California, 1994-1997. Circles = actual values; solid line = estimated values; dashed line = age at 50% maturity.

declining dramatically (Fig. 10). Spent-stage ovaries were present to some degree throughout most of the year, with the exception of August and December, with the highest frequencies occurring in February and March, directly following the peak spawning period. Transitional-stage ovaries were present throughout the year and immature-stage ovaries were present throughout the year with the exception of December. Ovaries in the maturing stage were present throughout most of the year, but were most prominent during the non-spawning season, particularly from May through September.

Ripe-stage testes began to appear in September and their frequency increased through the end of the spawning period in March (Fig. 11). Immature-stage testes were present throughout the entire year, with a marked increase from April through June. Transitional-stage testes were fairly prominent throughout the year, with a noticeable decline after the peak spawning period from March through June.

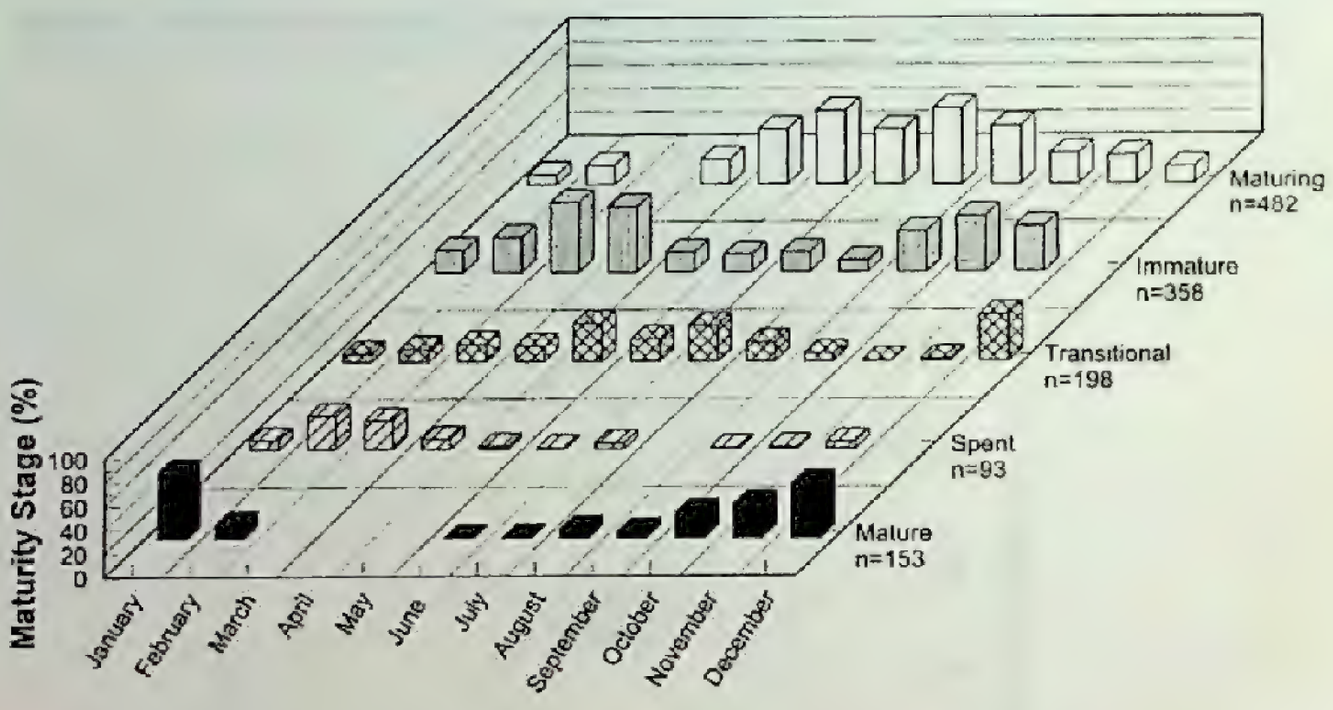

Figure 10. Percent maturity stage by month for female lingcod, *Ophiodon elongatus*, (n=1,284) from northern and central California, 1994-1997.

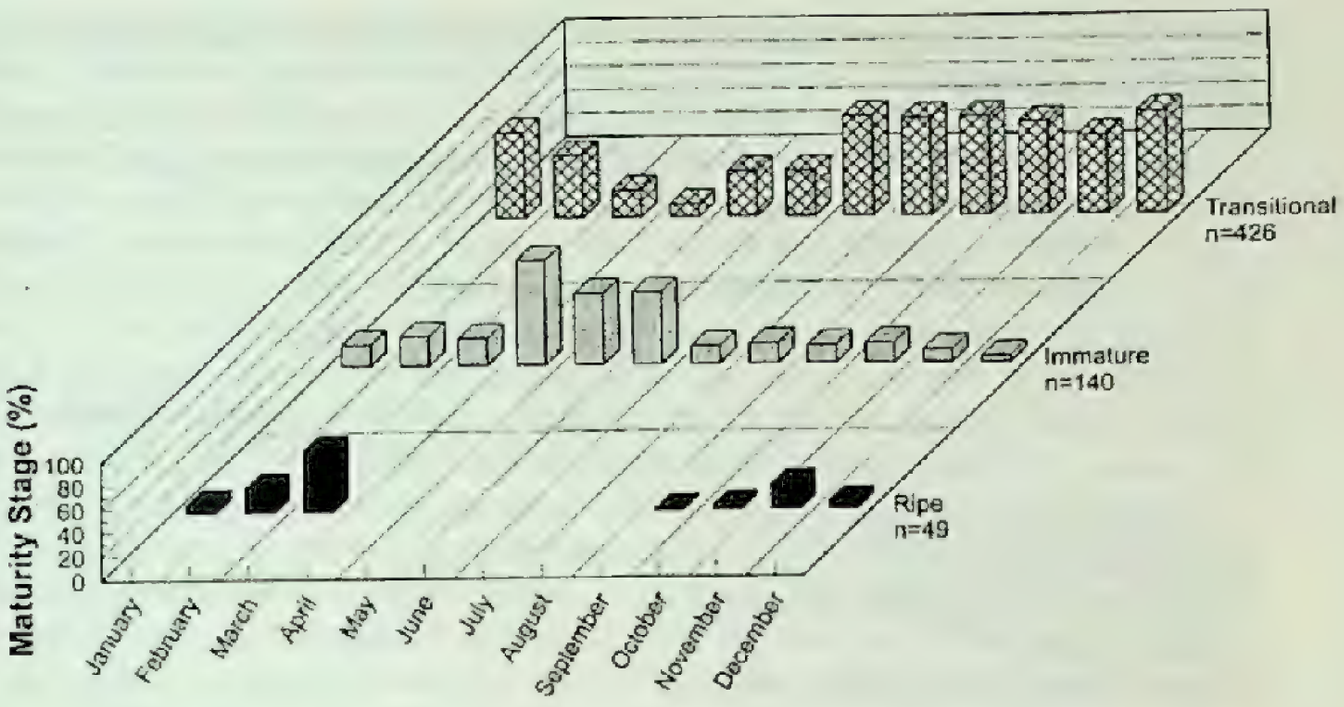

Figure 11. Percent maturity stage by month for male lingcod, *Ophiodon elongatus*, (n=615) from northern and central California, 1994-1997.

DISCUSSION

Lingcod lengths at 50% maturity found here differed somewhat from estimates calculated using earlier data for central California from Miller and Geibel (1973). Estimates of length at 50% maturity from Miller and Geibel's data (n=291) collected from central California were larger for females and smaller for males, than the values found here (Table 3). Based on our data, 45% of females and 80% of males reach sexual maturity at a size of 22-in (559-mm) TL versus 33% of females and 95% of males based on Miller and Geibel's data. Conversely, at the current 26-in (660-mm) TL size limit, which corresponds to 646 mm FL, data from the current study and from Miller and Geibel's study agree that an estimated 93% of females and 100% of males would reach sexual maturity.

To more accurately compare our data to the time period sampled by Miller and Geibel (1973), the length and age at 50% maturity were calculated using data taken only from the months of November through February. The values for length at 50% maturity for both females and males became very similar between the two studies with a only a 9 mm difference in females and 19 mm difference in males (Table 3). It is interesting that the length at 50% maturity for lingcod remained stable for a period of over 20 years. This occurred while the species was heavily exploited and different size regulations were put in place. The difference in age at 50% maturity may be due to differences in the aging methodology between the two studies. Miller and Geibel (1973) used surface aging of otoliths (which was the best available method at the time) while in this study we examined fin ray cross-sections. The surface aging of lingcod otoliths has been shown

to be unreliable by Beamish and Chilton (1977). Therefore, any comparison of age data would be impractical.

Table 3. Estimated fork length and age at 50% maturity for female and male lingcod, *Ophiodon elongatus*, by study area.

Study Area	Female		Male	
	Age (years)	Fork Length (mm)	Age (years)	Fork Length (mm)
Vancouver Island (Richards et al. 1990)	3.9	641	3.5	581
Washington (Jagielo 1994)[3]	4.6	634	3.4	513
Central California (Estimated from Miller and Geibel 1973)	4.7	582	2.2	423
Northern/Central California (current study)	3.8	557	3.2	461
Northern/Central California (current study) November through February.	4.3	591	2.9	442

[3]Jagielo, T. 1994. Assessment of lingcod (*Ophiodon elongatus*) in the area north of 45° 00' N (Cape Falcon) and south of 49° 00' N in 1994. Appendix I. *In* Pacific Fishery Management Council. 1994. Appendix: Status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995: Stock assessment and fishery evaluation. Pacific Fishery Management Council, 2130 SW Fifth Avenue, Suite 224, Portland, Oregon 97201.

Differences in length and age 50% maturity between year-round sampling and sampling during spawning times may be due to both sampling design problems and biologic factors. In this study, most samples came from the commercial trawl fishery which tends to fish in deeper water. Lingcod have been shown to have a seasonal migration pattern where mature males and females move into shallow water to spawn. After spawning, the females move back into deeper water, while the males remain to guard the nest. After hatching, a segment of mature males remains in shallow water. Therefore, during the spawning season, trawl samples could be biased toward immature females and males, while shallow-water sampling could be biased toward mature fish. Since trawl sample data was primarily used here, a year-round sampling program was used in an attempt to alleviate the bias from spawning migrations. This bias may actually be slight, however, because the difference between our lengths at 50% maturity for samples collected between November and February were similar to those of Miller and Geibel (1973) collected from commercial passenger fishing vessels (CPFV) over the same time period. Since the CPFV samples are typically caught in shallower water than trawls, a difference would be expected between the two sampling methods. However, only slight differences were found. This, then, shows that the bias in sampling method was low.

Many sampling differences exist between this study and the Miller and Geibel (1973) study, which may explain the inconsistencies in length at 50% maturity. The sample size used for this study was six times larger, and samples were collected over a broader geographical range than for the Miller and Geibel data, which were collected only from Monterey and Morro Bays. Furthermore, maturity criteria varied between the two studies. Miller and Geibel's maturity classification included only "near spawning," "spawning," and "spent" individuals. Maturity classes used here were based on the WDFW maturity stages for lingcod (Table 1), and for the purposes of this study fish from all maturity stages except immature were considered to be mature individuals. It is difficult to distinguish between immature and transitional maturity stages and this may have led to errors in the proportions of gonads assigned to these stages. An examination of gonadal histology throughout the year would resolve this problem.

Lingcod length at 50% maturity decreased from north to south for both females and males, but there was no corresponding trend in age at 50% maturity (Table 3). Female length at 50% maturity decreased from 641 mm for Vancouver Island to 557 mm for California. Similarly, for males, length at 50% maturity decreased from 581 mm for Vancouver Island to 461 mm for California. A similar decreasing north to south trend was observed for lengths of the smallest mature fish. Length of the smallest mature female was 700 mm (Forrester 1973) and 768 mm (Wilby 1937) for fish from Canadian waters, while it was 437 mm for California-caught fish. Length of the smallest mature male was 460 mm (Forrester 1973) and 520 mm (Wilby 1937) for Canada and 390 mm in California. Similar latitudinal trends have been observed for rockfish, genus *Sebastes* (Haldorson and Love 1991).

The concept of size at 50% maturity has been used for many species ranging from tanner crabs (Somerton and Donaldson 1996) to Puget Sound rockfish (Beckman et al. 1998) to red drum in the Gulf of Mexico (Wilson and Nieland 1994). The use of the size at 50% maturity ensures that 50% of the population will not be subject to fishing mortality and will have the opportunity to reproduce. Any minimum size limit above the 50% level would allow a greater proportion of the population to survive until spawning. At the current size limit of 26 inches (660 mm FL) in California, all of the male lingcod and all but 3 % of the females will have reached sexual maturity. With this increased reproductive capacity for lingcod, more successful spawning should occur which will give the population a better chance to rebuild.

ACKNOWLEDGMENTS

We thank B. Erwin, D. Thomas, and the samplers of the California Cooperative Groundfish Survey for collecting the length and maturity data, as well as the dorsal fin rays from the lingcod. Without their help this study would not have been possible. We would also like to thank all the people who helped prepare the fin rays for ageing and all the reviewers.

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Received: 12 March 2000
Accepted: 8 December 2001

CALIFORNIA FISH AND GAME
Calif. Fish and Game 87(4):153-167 2001

MUSEUM COLLECTION RECORDS OF MOUNTAIN LIONS IN CALIFORNIA

ERIC S. LONG and RICHARD SWEITZER
Department of Biology
University of North Dakota
Grand Forks, ND 58202

Mountain lions (*Puma concolor*) are widespread and abundant in western North America, including California. Historically, the management of mountain lions in California has varied with changing public perception and attitudes toward predators (Torres et al. 1996). Mountain lions in California were bountied from 1907 to 1963. During this period 12,461 mountain lions were killed, which potentially reduced population numbers statewide (Torres et al. 1996). Following the bounty period, mountain lions were unprotected and unregulated until 1969, when they were classified as game mammals. One hundred eighteen mountain lions were harvested before California enacted a moratorium on hunting the species midway through the 1972 season (Torres et al. 1996). After 1972, mountain lions have been protected from hunting except when individual animals are documented to threaten public safety or kill livestock or pets (i.e., depredation). Because of this protection, mountain lion populations in California have likely increased, as supported by the steady rise of depredation incidents since 1972 (Torres et al. 1996, Torres[1] 2000). Public concerns regarding increased mountain lion depredation incidents has translated into increased management and scientific attention directed toward the species (Ernest et al. 2000, Hayes et al. 2000, Pierce et al. 2000).

Like many other large predators, mountain lions are elusive and difficult to study, and large data sets pertinent to scientific research are rare (Anderson[2] 1983). Depredation records on mountain lions in California beginning in 1972 are one important source of data useful for research. Several recent studies have used depredation records and depredation-related information (e.g. necropsies) to assess physical characteristics of mountain lions (Charlton et al. 1998) and recent potential trends in population size and distribution (Torres et al. 1996). Museum collections are another valuable source of scientific information on wildlife species. Museum records and specimens can be used for morphological research (Gay and Best 1996), studies of population genetic structure (Bouzat et al. 1998), and estimating species distributions (Meaney and Van Vuren 1993, Reznick et al. 1994). Because museums and museum records are widely dispersed, however, detailed and comprehensive lists of museum

[1]Torres, S.G. 2000. Counting cougars in California. Outdoor California 61(3):7-9.

[2]Anderson, A.E. 1983. A critical review of the literature on puma (*Felis concolor*). Denver, CO: Colorado Division of Wildlife. Special Report 54. 91pp.

specimens for a particular species are seldom available. Our objectives were to (1) compile a detailed list of mountain lion museum specimens from California available in U.S.-based museums, and (2) compare the historical distribution of mountain lions in California, based on collection localities, with recent estimates of the distribution of mountain lions based on habitat (Torres et al. 1996).

We queried 33 museums from across the country (Hafner et al. 1997) regarding their holdings of mountain lions from California. Seventeen of these museums reported records for 280 mountain lion specimens (skin and/or skeletal materials), representing 194 unique locations in 44 counties in California (Appendix A). The University of California, Berkeley, Museum of Vertebrate Zoology (MVZ) accounted for over one-third of all identified specimens (n = 99). Mountain lion specimen collection dates ranged from 1871 to 1995, but most were collected between 1900-1930 and 1970-1990 (Fig. 1). The distinct temporal variation in collection records likely reflects some combination of change in abundance of mountain lions, economic conditions, and dynamics of efforts by museums to obtain specimens.

The majority of specimen records lacked geographic coordinates, which we estimated by plotting collection localities using a searchable, computerized topographic map program, TOPO (Wildflower Productions, San Francisco, CA 2000). The accuracy

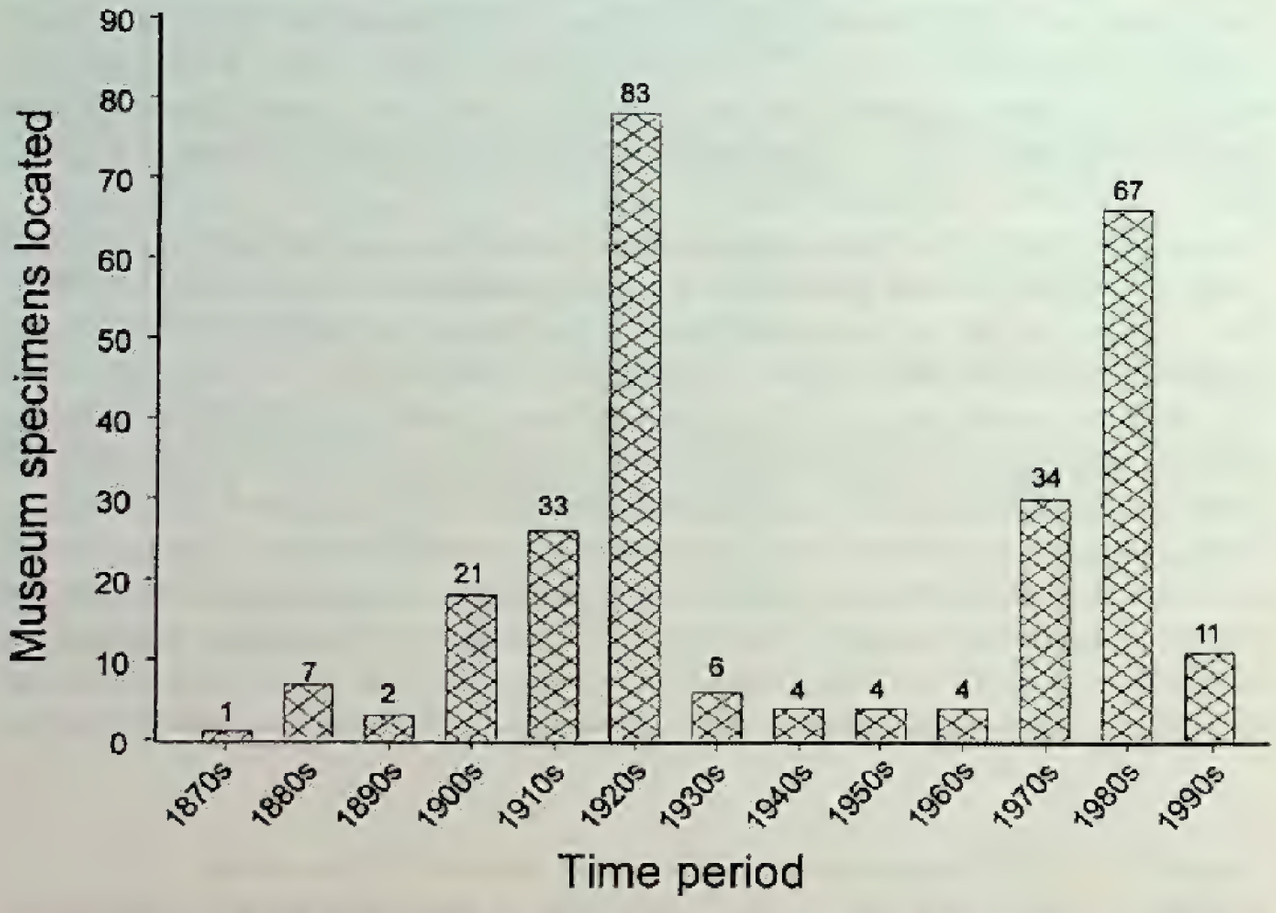

Figure 1. Temporal distribution by decade of museum records of mountain lions from California.

of estimated geographic coordinates varied based on the detail provided for collection localities, but likely were within one U.S. geological survey 7 ½' quadrangle. Records for two museum specimens included geographic coordinates but lacked collection localities, and records for 26 specimens included only county names (Appendix A). Three specimens included collection locality records that were too general to permit mapping, or listed old place names that were not found on current maps (Appendix A).

Estimated geographic coordinates were used to generate a map of mountain lion collection locations in California (Fig. 2). Museum records indicated that mountain lions specimens were most often associated with regions of rugged topography, and

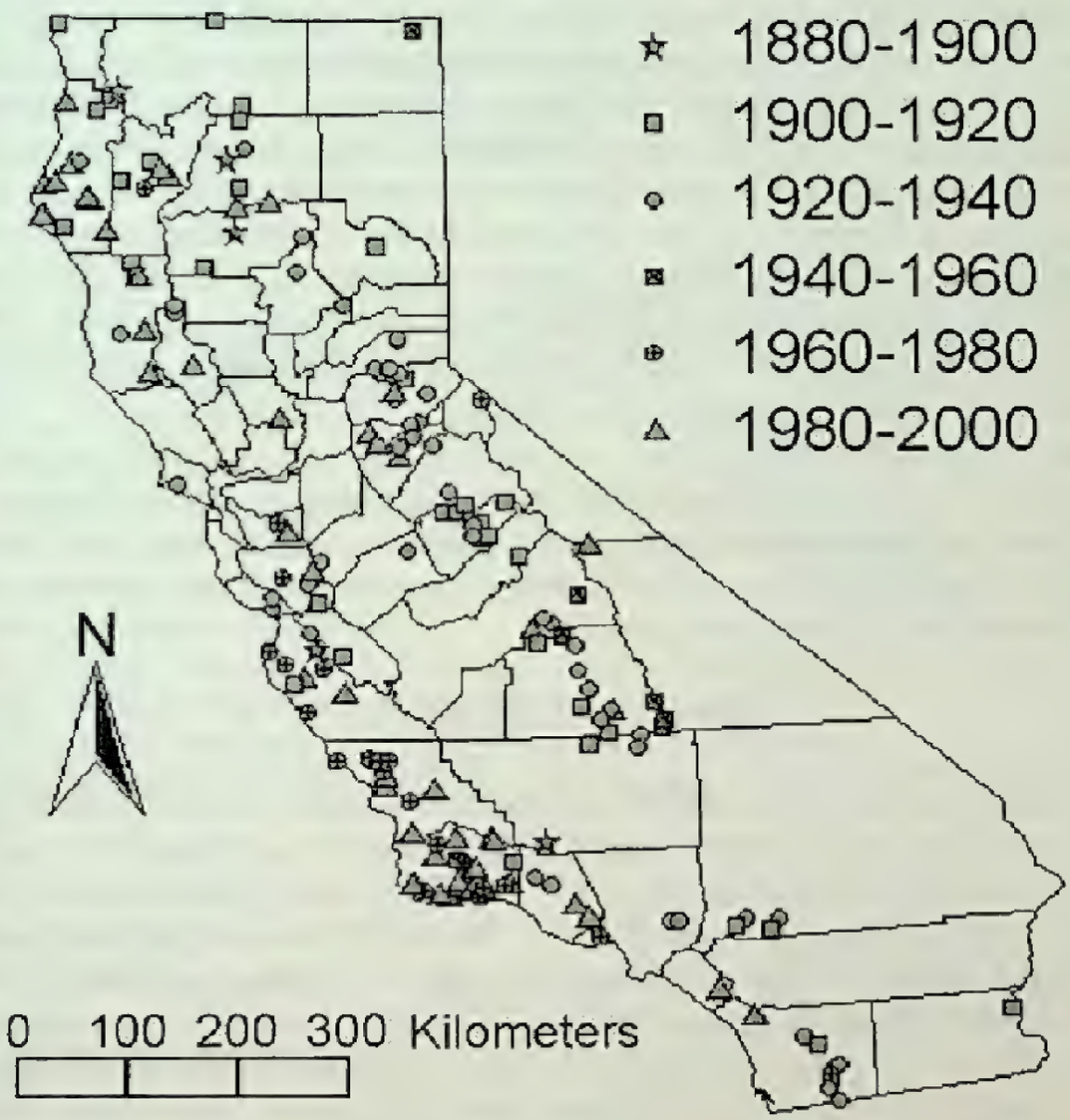

Figure 2. Distribution of mountain lions in California based on collection localities of museum specimens.

avoided lowland areas such as the Central Valley and the Mojave Desert regions (Fig. 2). Four specimens were collected in the Central Valley region before 1921, however. Prior to the early 1900's, when intensive agricultural development began in the area, the Central Valley region of California was a mosaic of oak woodland, oak savannah, grassland and riparian habitats along several major rivers (Pavlik et al. 1991). Historical accounts suggest that this now agriculture-dominated landscape supported a diversity of native wildlife including grizzly bears, deer, and likely mountain lions (Jameson 1988, Steinhart 1990). The lack of modern specimens from the area suggests that anthropogenic modification of habitat has contributed to the absence of mountain lions from the region.

A comparison of the mapped distribution of mountain lion museum specimens to a recently published estimate of the distribution of mountain lions based on habitat suitability (Torres et al. 1996) indicated a high level of concordance. Most of the areas identified by Torres et al. (1996) as having high or medium suitability for mountain lions were regions where multiple mountain lion museum specimens were collected (Fig. 2). The largest disparity between the 2 distribution maps was the relative lack of museum specimens north of the San Francisco Bay region (Marin, Sonoma, Napa, and Lake Counties). Based on habitat features, there also were fewer museum records than expected in the northwestern corner of the state (Del Norte and Siskiyou Counties) and, to a lesser extent, in the southern part of the state (Orange, Kern, and Riverside Counties). In contrast, more mountain lions than expected were collected from Santa Barbara and Ventura Counties. These apparent discrepancies between the distribution maps were most likely the result of sampling bias in the museum record.

Nearly all museums with which we have worked on this study support and encourage research use of collection specimens. We hope that the publication of an extensive and synthesized list of museum records for mountain lions from California will facilitate and stimulate additional research on morphology, systematics, and genetics of mountain lions from California.

ACKNOWLEDGMENTS

We thank the many museums who provided access to their records and specimens: California Academy of Sciences (CAS); California Polytechnic State University, San Luis Obispo (CPSU); California State University, Chico, Vertebrate Museum (CSUC); California State University, Fresno (CSUF); The Field Museum (FMNH); Humboldt State University (HSU); Natural History Museum of Los Angeles County (LACM); Pacific Grove Museum of Natural History (PGMNH); San Diego Natural History Museum (SDNHM); San Jose State University, Museum of Birds and Mammals (MBM); Santa Barbara Museum of Natural History (SBMNH); United States National Museum of Natural History (USNM); University of Alaska Museum (UAM); University of California, Berkeley, Museum of Vertebrate Zoology (MVZ); University of California, Davis, Museum of Wildlife and Fisheries Biology (MWFB); University of California, Los Angeles, Dickey Collection (UCLA); University of Kansas, Museum of Natural History (KU); Yale University, Peabody Museum of Natural History (YPM). V. Bleich,

R. Crawford and two anonymous reviewers provided helpful comments that improved the manuscript.

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Received: 30 August 2001
Accepted: 15 February 2002

Appendix A. Holdings of 17 US museums of mountain lions from California.

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
Alameda	Livermore area	37.68	-121.77	9/1/70	CAS	1760
Alameda	S Livermore, Deral Canyon, Mines Road mile 80	37.61	-121.69	5/17/87	MVZ	175990
Alpine	Leviathon Mine Road	38.70	-119.67	1/12/75	CAS	16671
Amador	2 miles S Lumberyard Ranger Station	38.52	-120.31	9/13/27	MVZ	38340
Amador	3 miles S Lumberyard Ranger Station	38.51	-120.31	9/13/27	MVZ	38341
Amador	Drytown	38.44	-120.85	9/24/85	MVZ	175987
Amador	Drytown	38.44	-120.85	9/24/85	MVZ	186056
Amador	Near Jackson	38.34	-120.76	9/24/87	MWFB	2438
Amador	Near Jackson	38.34	-120.76	9/25/87	MWFB	2437
Amador	Near Panther Creek	38.49	-120.41	1925-28	KU	48098
Amador				1984	MWFB	2116
Amador				1960s	CAS	184
Butte	Empire Creek N of Sawmill Peak	39.83	-121.56	1926	UCLA	16409
Calaveras	1 mile S Folsom Ranger Station, 3 miles N Blue Mt.	38.39	-120.37	8/13/32	MVZ	53384
Calaveras	5 miles E Dorrington	38.31	-120.19	10/26/28	MVZ	40142
Calaveras	Mountain Ranch	38.23	-120.54	8/18/84	MVZ	175986
Calaveras		38.30	-120.52	10/26/24	MVZ	40143
Del Norte	Smith River	41.93	-124.15	12/23/04	USNM	139783
Del Norte	Smith River	41.93	-124.15	1904	USNM	139782
El Dorado	3 miles N Bald Mt.	38.95	-120.71	1926	UCLA	16041
El Dorado	4 miles N Blacksmith Flat	38.99	-120.75	9/10/22	MVZ	38312
El Dorado	4 miles SE Uncle Tom's Cabin	38.90	-120.44	8/11/27	MVZ	38308
El Dorado	5 miles W Uncle Tom's Cabin	38.92	-120.60	9/8/27	MVZ	38339
El Dorado	Cool	38.90	-120.45	5/1/11	MVZ	12690
El Dorado	E Sly Park	38.72	-120.57	7/22/22	MVZ	38311
El Dorado	Near Bald Mt.	38.76	-120.22	1925-28	KU	48093

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
El Dorado	Uncle Tom	38.94	-120.50	1925-28	KU	48092
El Dorado	Uncle Tom	38.94	-120.50	1925-28	KU	48096
El Dorado	Uncle Tom	38.94	-120.50	1925-28	KU	48097
El Dorado		38.78	-120.59	4/3/83	MVZ	186058
Fresno	7 miles NE Dunlap	36.79	-119.03	1/14/24	MVZ	33557
Fresno	Dark Canyon, 5 miles N Dunlap	36.82	-119.12	1/13/24	MVZ	33556
Fresno	Near Poison Meadow head of Blue Canyon	37.01	-118.73	9/27/46	MWFB	1759
Fresno/Tulare	Squaw Valley	36.74	-119.25	12/31/85	CSUF	
Humboldt	Alder Point	40.18	-123.61	12/19/85	MWFB	2691
Humboldt	Alder Point	40.18	-123.61	12/20/89	MWFB	2653
Humboldt	Bridgeville	40.45	-123.79	5/31/92	HSU	7167
Humboldt	Camp Creek	41.29	-123.56	1916	CAS	734
Humboldt	Ferndale	40.57	-124.26	6/29/88	HSU	4610
Humboldt	Ferndale	40.57	-124.26	8/20/88	HSU	4609
Humboldt	Ferndale	40.57	-124.26	2/9/90	HSU	5136
Humboldt	Ferndale	40.57	-124.26	4/2/92	HSU	6991
Humboldt	Fortuna	40.60	-124.15	10/4/91	HSU	7165
Humboldt	Kneeland	40.75	-123.99	4/30/92	HSU	6992
Humboldt	Lowry	39.90	-123.32	2/21/12	CAS	563
Humboldt	Maple Creek	40.76	-123.86	5/1/33	MVZ	58874
Humboldt	Near Bridgeville	40.47	-123.81	10/31/81	MWFB	2514
Humboldt	Near Bridgeville	40.47	-123.81	10/31/81	MWFB	2513
Humboldt	Near Bridgeville	40.47	-123.81	11/1/85	MWFB	2391
Humboldt	Near Bridgeville	40.47	-123.81	11/1/85	MWFB	2393
Humboldt	Near Bridgeville	40.47	-123.81	11/2/85	MWFB	2392
Humboldt	Near Fortuna	40.60	-124.16	11/5/89	MWFB	2574
Humboldt	Near Petrolia	40.32	-124.27	3/21/85	HSU	4285
Humboldt	Near Petrolia	40.32	-124.27	3/30/85	HSU	4284
Humboldt	Orick	41.28	-124.06	9/27/91	HSU	7166

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
Humboldt	Paskenta	39.88	-122.55	5/6/12	CAS	570
Humboldt	Petrolia	40.31	-124.28	8/20/91	HSU	6728
Humboldt	Petrolia, Fieldbrook area	40.31	-124.28	1992	HSU	7172
Humboldt	Upper Mattole	40.21	-124.04	11/9/05	USNM	146260
Humboldt	Weitchpec	41.19	-123.71	2/21/12	CAS	564
Humboldt	Weitchpec	41.19	-123.71	4/16/12	CAS	567
Humboldt				10/30/88	HSU	4608
Imperial	20 miles N Picacho, Colorado River	33.29	-114.74	11/15/09	MVZ	10586
Inyo	Tunawee Canyon	36.06	-118.02	3/30/36	MVZ	90976
Inyo	Tunawee Canyon	36.06	-118.02	3/30/40	MVZ	90975
Inyo	Wells Meadow	37.44	-118.65	6/24/85	MVZ	186057
Inyo	Wells Meadow	37.44	-118.65	6/25/89	MVZ	186057
Inyo	Wells Meadow	37.44	-118.65	6/25/89	MVZ	186057
Kern	2 miles S of W End Long Valley	35.80	-118.17	10/23/23	MVZ	33553
Kern	3 miles S of W End Long Valley	35.79	-118.17	10/23/23	MVZ	33554
Kern	9 Miles Canyon	35.84	-117.96	4/11/57	LACM	43286
Kern	9 Miles Canyon, Little Lake	35.91	-117.92	4/14/57	LACM	43285
Kern	Glenville	35.73	-118.70	4/6/10	CAS	217
Kern	Green Horn Mtns	35.82	-118.49	4/5/10	CAS	216
Kern	San Emigdio Canyon, San Emidio	34.93	-119.15	10/19/1891	USNM	A0043406
Kern	Scodie/ Kaviah Mt.	35.69	-118.22	2/1/32	MVZ	59972
Lake	Brush Camp Ridge	39.47	-122.86	1925-28	KU	48088
Lake	Brush Camp Ridge	39.47	-122.86	1925-28	KU	48089
Lake	Brush Camp Ridge	39.47	-122.86	1925-28	KU	48090
Lake	Brush Camp Ridge	39.47	-122.86	1925-28	KU	48091
Lake	Clearlake Oaks	39.03	-122.66	1/27/85	UAM	15985
Lake				1904	USNM	131497
Los Angeles	Los Angeles, Mulholland	34.10	-118.66	4/17/72	LACM	52223
Los Angeles	Monrovia Peak	34.21	-117.97	2/1/29	UCLA	15354

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
Los Angeles	W Fork Roberts Canyon	34.21	-117.90	3/1/29	UCLA	15355
Madera	Blue Creek	36.05	-118.76	4/6/09	CAS	33069
Madera	Sierra National Forest	37.37	-119.34	1907	USNM	266108
Madera	Sierra National Forest	37.37	-119.34	1907	USNM	266107
Marin	Marin Country Club, Bear Valley near Olema	38.01	-122.80	3/21/31	MVZ	47199
Mariposa	2 miles E Dudley	37.75	-120.08	11/7/12	MVZ	31242
Mariposa	3 miles N Stage Station	37.75	-119.95	1/25/19	MVZ	33471
Mariposa	3 miles N Stage Station	37.75	-119.95	1/26/23	MVZ	33471
Mariposa	3 miles NE Wawona	37.55	-119.68	11/29/27	MVZ	40148
Mariposa	7.5 miles W Wawona	37.53	-119.70	3/8/16	MVZ	23745
Mariposa	8 miles W Wawona	37.55	-119.80	2/7/28	MWFB	13
Mariposa	Bishop Creek	37.61	-119.72	11/1/29	UCLA	16421
Mariposa	Chinquapin; Yosemite National Park	37.65	-119.70	12/13/18	MVZ	29799
Mariposa	Panoche Peak	37.63	-119.78	1927	UCLA	16461
Mariposa	Virginia/Devil Creek	37.54	-119.79	1/26/25	CAS	5247
Mariposa	Virginia/Devil Creek	37.54	-119.79	1/26/26	CAS	5230
Mariposa	Wawona	37.54	-119.64	12/3/15	MVZ	23653
Mariposa	Wawona	37.54	-119.64	1/8/16	MVZ	23654
Mariposa	Wawona	37.54	-119.64	1/20/16	MVZ	23652
Mariposa	Wawona	37.54	-119.64	1/20/16	MVZ	23655
Mendocino	Corbin Creek and S Fork Eel	39.53	-122.85	1/1/22	CAS	4389
Mendocino	Corbin Creek and S Fork Eel	39.53	-122.85	3/1/22	CAS	4388
Mendocino	Corbin Creek and S Fork Eel	39.53	-122.85	3/1/22	CAS	4390
Mendocino	Covelo	39.79	-123.25	8/9/16	USNM	224568
Mendocino	Hopland	38.97	-123.12	6/14/84	MWFB	2596
Mendocino	Near Covelo	39.79	-123.25	8/15/73	MWFB	964
Mendocino	Near Covelo	39.79	-123.25	9/19/84	HSU	4263
Mendocino	Rice and Connor's Creek	39.30	-123.40	1/6/28	MVZ	38891
Mendocino	Van Arsdale Ranch, 12 miles N Ukiah	39.33	-123.19	3/4/83	HSU	4264

County	Location	Latitude	Longitude	Date	Museum[1]	Catalog#
Mendocino					FMNH	16023
Merced	8 miles NE Merced on road to Snelling	37.42	-120.45	6/23/20	MVZ	31896
Modoc	Buck Creek	41.87	-120.30	1/31/53	MVZ	129729
Monterey	Bryson Canyon, Merle Ranch	36.05	-121.49	12/15/76	MBM	2849
Monterey	Carmel Valley Road	36.46	-121.70	12/2/78	CAS	21430
Monterey	Carmel Valley Road	36.46	-121.70	12/2/78	CAS	21430
Monterey	Hastings Nat. History Res., 2.5 miles E Jamesburg	36.37	-121.54	12/11/95	MVZ	190994
Monterey	Hastings Reservation	36.37	-121.54	10/26/85	MVZ	172401
Monterey	King City	36.22	-121.12	10/1/81	CPSU	2434
Monterey	Laguna Ranch, Gabilan Range	36.60	-121.40	2/3/1893	USNM	65370
Monterey	Monterey Peninsula region	36.59	-121.87	8/23/75	PGMNH	
Monterey	Pine Valley	36.30	-121.63	4/18/19	MVZ	33429
Monterey	Pine Valley	36.30	-121.63	4/19/23	MVZ	33430
Monterey	Soledad area	36.42	-121.33	9/1/79	CAS	3037
Monterey				4/18/74	CAS	21510
Monterey				4/18/74	CAS	21510
Monterey				3/28/78	MBM	3085
Monterey				11/7/81	CAS	2962
Nevada				1974	MWFB	1330
Orange	Bell Canyon Starr Ranch Audubon Sanctuary	33.62	-117.55	8/29/89	MVZ	186055
Placer	2 miles S Sugar Pine Ranger Station	39.22	-120.54	8/14/27	MVZ	38309
Placer	6 miles N Forestville			8/6/29	MWFB	116
Placer	Lynchburg	38.99	-120.62	7/16/20	MVZ	31251
Placer	Lynchburg	38.99	-120.62	7/21/20	MVZ	31252
Placer	Sugar Pine	39.25	-120.54	1927	UCLA	16401
Plumas	Genesee	40.04	-120.75	2/4/02	USNM	140642
Riverside	Strawberry Creek, 0.5 mile up road to Hemet Lake	34.20	-117.23	6/9/25	MVZ	34991
San Benito	4 miles S Fremont Peak; 14 miles from Hollister	36.73	-121.45	12/20/24	MVZ	34308
San Benito	Cook	36.53	-121.14	12/13/04	CAS	20678

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
San Bernadino	1.5 miles NE Seven Oaks	34.18	-119.92	1925	UCLA	15475
San Bernadino	Coxes' Ranch, San Bernadino Mtns.	34.14	-117.35	8/1/06	MVZ	7145
San Bernadino	Mill Creek Canon, San Bernadino Mtns.	34.10	-117.01	1913	MVZ	24534
San Diego	2 miles SW Laguna Indian Reservation	32.89	-116.50	1/16/27	MVZ	37424
San Diego	2 miles W Laguna Indian Reservation	32.91	-116.44	1/16/27	MVZ	37425
San Diego	2 miles W Laguna Indian Reservation	32.91	-116.44	1/17/27	MVZ	37426
San Diego	Buckman Springs	32.77	-116.54	5/13/25	SDNHM	5064
San Diego	Campo	32.61	-116.47	2/1/27	SDNHM	5986
San Diego	Fallbrook	33.38	-117.25	2/17/83	SDNHM	23697
San Diego	Fallbrook	33.38	-117.25	12/15/87	SDNHM	23802
San Diego	Mesa Grande	33.18	-116.77	1/19/28	SDNHM	6749
San Diego	Pine Valley	32.82	-116.53	8/1/79	SDNHM	22873
San Diego	S base of Los Pinos Mtns.	32.73	-116.57	1/5/27	MVZ	37423
San Diego	Smith Mtns.			1920	SDNHM	2586
San Diego	Wynola	33.09	-116.64	6/7/06	MVZ	10856
San Diego	Wynola	33.09	-116.64	6/7/06	MVZ	10857
San Diego				6/1/79	SDNHM	23450
S.L. Obispo	1.5 miles E San Luis Obispo Reservoir	35.28	-120.47	10/18/75	CPSU	1347
S.L. Obispo	20 miles E Santa Margarita	35.39	-120.26	10/1/81	CPSU	2265
S.L. Obispo	3 miles E Zaca Lake	34.78	-119.99	2/12/21	MVZ	32328
S.L. Obispo	8 miles W Paso Robles	35.63	-120.83	8/1/75	MVZ	155331
S.L. Obispo	Adelaida	35.65	-120.87	8/1/76	CPSU	1559
S.L. Obispo	Hwy 41, 0.5 miles W Cerro Alto	35.42	-120.75	8/29/85	CPSU	2425
S.L. Obispo	Nipomo	35.04	-120.48	3/10/87	SBMNH	M-2601
S.L. Obispo	Paso Robles	35.63	-120.69	1979	CPSU	2039
S.L. Obispo	San Simeon	35.64	-121.19	3/1/76	CPSU	1560
S.L. Obispo	W of Atascadero	35.49	-120.74	2/23/81	CPSU	2189
S.L. Obispo	W of Templeton	35.55	-120.75	12/1/75	CPSU	1374
S.L. Obispo	W of Paso Robles	35.63	-120.77	1966	CPSU	1037
S.L. Obispo				11/1/54	CPSU	319

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
S.L. Obispo				7/19/60	CPSU	279
S.L. Obispo				9/13/70	CAS	21511
S.L. Obispo				9/14/74	CAS	21511
S.L. Obispo				11/11/81	CPSU	2267
S.L. Obispo				1/21/83	CPSU	2314
S.L. Obispo				9/1/85	CPSU	2426
San Mateo	Head of Gazos Creek	37.20	-122.24		MVZ	4919
Santa Barbara	15 miles NE of Sisquoc	34.98	-120.06	7/2/81	SBMNH	M-2013
Santa Barbara	20 miles N El Capitan Ranch	34.76	-119.98	1/4/76	LACM	70295
Santa Barbara	3 miles up San Marcos Pass road on Hwy 154	34.51	-119.74	11/26/75	SBMNH	918
Santa Barbara	9 miles SE of Lompoc on Hwy 1	34.54	-120.36	8/8/75	SBMNH	M-1237/886
Santa Barbara	Agua Caliente Canyon, Upper Santa Ynez Valley	34.58	-119.53	8/1/83	SBMNH	M-2159
Santa Barbara	Arroyo Honda Ranch	34.48	-120.12	9/7/89	SBMNH	M-2948
Santa Barbara	Branch Canyon, New Cuyama	34.97	-119.71	2/17/81	SBMNH	M-2012
Santa Barbara	Cuyama Range	34.75	-119.48	12/28/09	CAS	125
Santa Barbara	Gohrlater Road			4/9/88	LACM	85437
Santa Barbara	Golata-Tejijuas Ranch	34.48	-120.04	12/20/75	LACM	70297
Santa Barbara	Hwy 101 entrance to Gaviota State Park	34.50	-120.23	9/28/92	SBMNH	M-3100
Santa Barbara	Hwy 154 adjacent Cachuma Lake Entrance	34.57	-119.96	1/27/87	SBMNH	3987
Santa Barbara	Hwy 154 near Cold Springs Bridge	34.53	-119.83	6/25/79	SDNHM	23475
Santa Barbara	Hwy 154 near entrance to Lake Cachuma Co. Park	34.57	-119.96	9/30/94	SBMNH	4744
Santa Barbara	Hwy 154 W Cachuma Lake	34.61	-120.05	1/22/80	SBMNH	M-2010
Santa Barbara	Hwy 154, mile marker 19.5, near Lake Cachuma	34.54	-119.90	6/10/83	SBMNH	M-2158
Santa Barbara	Las Vagas Canyon	34.47	-119.83	3/25/74	SBMNH	887
Santa Barbara	Lillington Canyon Road, Pinkham Ranch	34.73	-119.88	6/22/84	SBMNH	M-2177
Santa Barbara	Lompoc, 1500 Miguelito Canyon	34.61	-120.46	2/27/87	SBMNH	M-2382
Santa Barbara	Miguelito Canyon	34.61	-120.50	5/6/88	LACM	85440
Santa Barbara	N Fork Santa Ynez River 20 miles NE Santa Barbara			1925	UCLA	10111
Santa Barbara	New Cuyama	34.95	-119.68	12/3/81	SBMNH	M-2048
Santa Barbara	Paradise, Santa Ynez Valley	34.54	-119.81	1/21/88	SBMNH	M-2676

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
Santa Barbara	Rancho San Fernando Rey, E of Cachuma Lake	34.55	-119.78	1/4/79	SBMNH	M-1899
Santa Barbara	Rancho Sisquoc, Long Canyon	34.84	-120.28	2/13/88	LACM	85438
Santa Barbara	Tepusquet Canyon, Santa Maria	34.92	-120.23	3/19/74	SBMNH	889
Santa Barbara	Upper Santa Ynez River, near Agua Caliente Canyon	34.56	-119.56	2/5/78	SBMNH	M-1959
Santa Barbara	Zaca Lake	34.78	-120 04	8/3/40	SBMNH	238
Santa Clara	10 miles E Gilroy	37.00	-121.38	5/18/05	CSUC	
Santa Clara	16 miles SE Mt. Hamilton	37.16	-121.48	6/25/23	MVZ	33452
Santa Clara	2 miles E Colt Flat			3/11/23	MVZ	33427
Santa Clara	2 miles E Colt Flat			3/12/23	MVZ	33428
Santa Clara	8.5 miles S of head of Soquel Creek	36.96	-121.82	5/3/33	MVZ	59677
Santa Clara	San Felipe Ranch; 13.3 miles SE San Jose	37.21	-121.72	9/20/69	MVZ	165914
Santa Cruz	1 mile S head of Soquel Creek	37.05	-121.82	6/8/23	MVZ	33451
Santa Cruz				4/28/80	MBM	3162
Shasta	1 mile N Squaw Creek Ranger Station	40.88	-122.12	11/17/25	MVZ	35375
Shasta	1 mile N Squaw Creek Ranger Station	40.88	-122.12	11/17/25	MVZ	35376
Shasta	Baird	40.79	-122.30	10/15/1883	USNM	A0021078
Shasta	Baird	40.79	-122.30		USNM	14471
Shasta	Cottonwood, Whitmore Road	40.40	-122.23	10/1/84	MVZ	175984
Shasta	Hyampom	40.62	-123.45	10/27/11	CAS	483
Shasta	Manfon	40.44	-121.87	6/1/83	MVZ	175985
Shasta	McCloud Station	41.26	-122.14	10/1/09	MVZ	8868
Shasta	Millville	40.55	-122.18	10/26/07	CAS	484
Shasta	Red Bluff	40.18	-122.24	03/29/1884	USNM	14469
Shasta	Squaw Valley Creek, 4 miles W McCloud Clubhouse	41.13	-122.16	6/24/11	MVZ	14711
Shasta				4/25/1884	USNM	A0021244
Shasta				8/20/1884	USNM	A0021526
Shasta				8/20/1884	USNM	A0021527
Shasta				8/20/1884	USNM	A0021528
Siskiyou	Camp Creek	41.97	-122.45	5/4/09	CAS	696
Siskiyou	Paskenta	39.88	-122.55	4/25/13	CAS	695

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
Siskiyou	Salmon River	41.38	-123.49	1898	USNM	96155
Siskiyou	Weitchpec	41.19	-123.71	4/20/12	CAS	573
Stanislaus	N Fork Orestimba Creek	37.35	-121.35	1/8/25	MVZ	34302
Stanislaus	N Fork Orestimba Creek	37.35	-121.35	1/8/25	MVZ	34303
Stanislaus	Red Creek headwater	37.29	-121.44	5/1/89	MBM	2694
Tehama	Colby Mt. area, S Edge Tehama Co.	40.14	-121.51	1927	UCLA	16410
Tehama	Millville	40.55	-122.18	2/26/08	CAS	485
Tehama	Paskenta	39.88	-122.55	2/5/12	CAS	486
Tehama	Paskenta	39.88	-122.55	3/14/12	CAS	522
Tehama	Paskenta	39.88	-122.55	4/2/12	CAS	557
Tehama	Paskenta	39.88	-122.55	4/2/12	CAS	555
Tehama	Paskenta	39.88	-122.55	4/30/12	CAS	556
Tehama	Weitchpec	41.19	-123.71	5/3/08	CAS	569
Trinity	Douglas City	40.65	-122.94	5/5/87	HSU	6183
Trinity	Hayfolk area	40.55	-123.18	1979	CAS	3036
Trinity	Helena	40.77	-123.13	2/27/11	MVZ	12871
Trinity	Junction City	40.73	-123.05	5/29/87	HSU	4848
Trinity				6/19/24	MVZ	34283
Trinity				11/1/78	CAS	3035
Tulare	25 miles N of Kernville	36.01	-118.47	9/1/83	MVZ	175988
Tulare	6 miles NE Badger	36.67	-118.91	2/25/46	MVZ	184081
Tulare	Camp Wishera	36.19	-118.67	1925-28	KU	48094
Tulare	Camp Wishera	36.19	-118.67	1925-28	KU	48095
Tulare	Clough Cave, S Fork Kaweah River	36.35	-118.76	2/16/24	MVZ	34223
Tulare	Clough Cave, S Fork Kaweah River	36.35	-118.76	2/16/24	MVZ	34224
Tulare	Clough Cave, S Fork Kaweah River	36.35	-118.76	2/16/24	MVZ	34225
Tulare	Clough Cave, S Fork Kaweah River	36.35	-118.76	2/16/24	MVZ	34226
Tulare	Clough Cave, S Fork Kaweah River	36.35	-118.76	2/16/24	MVZ	34227
Tulare	Head BrushCrk,25 miles N Kernville, EsideKern River	36.01	-118.47	3/25/24	MVZ	34180

County	Location	Latitude	Longitude	Date	Museum[a]	Catalog#
Tulare	Head of Pack Saddle Creek	35.94	-118.58	3/27/24	MVZ	34251
Tulare	Manikin Flat, near Kaweah	36.60	-119.16	1/10/08	MVZ	7149
Tulare	Marble Fork Bridge	36.57	-118.78	1/26/24	MVZ	33558
Tulare	Marble Fork Bridge	36.57	-118.78	1/26/24	MVZ	33559
Tulare	Marble Fork Bridge	36.57	-118.78	1/26/24	MVZ	33560
Tuolumne	Crockers	37.80	-119.88	1916	MVZ	29798
Tuolumne	Crockers	37.80	-119.88	1918	MVZ	29800
Tuolumne	Near Femmon's Meadow	37.93	-120.02	7/24/23	MVZ	33555
Tuolumne	Yosemite National Park	37.83	-119.46	1918	MVZ	29797
Ventura	Fillmore	34.40	-118.92	1/4/84	SBMNH	3037
Ventura	Hwy 18, Simi	34.27	-118.78	12/8/87	SBMNH	3558
Ventura	Hwy 18, Simi	34.27	-118.78	12/8/87	SBMNH	3558
Ventura	Pine Mt.	34.63	-119.28	4/14/26	MVZ	36468
Ventura	Sespe River	34.55	-119.13	4/13/26	MVZ	36467
Ventura				11/1/29	UCLA	18298
Yolo	Davis	38.57	-121.78	12/21/85	MWFB	2693
Yuba	Region of Strawberry Valley	39.53	-121.10	7/1/29	MVZ	44136
Unknown				1871	YPM	2655

[a] Acronyms from Hafner et al. (1997): California Academy of Sciences (CAS); California Polytechnic State University, San Luis Obispo (CPSU); California State University, Chico, Vertebrate Museum (CSUC); California State University, Fresno (CSUF); The Field Museum (FMNH); Humboldt State University (HSU); Natural History Museum of Los Angeles County (LACM); Pacific Grove Museum of Natural History (PGMNH); San Diego Natural History Museum (SDNHM); San Jose State University, Museum of Birds and Mammals (MBM); Santa Barbara Museum of Natural History (SBMNH); United States National Museum of Natural History (USNM); University of Alaska Museum (UAM); University of California, Berkeley, Museum of Vertebrate Zoology (MVZ); University of California, Davis, Museum of Wildlife and Fisheries Biology (MWFB); University of California, Los Angeles, Dickey Collection (UCLA); University of Kansas, Museum of Natural History (KU); Yale University, Peabody Museum of Natural History (YPM).

REFEREE ACKNOWLEDGMENTS

The following individuals have reviewed manuscripts for *California Fish and Game* during 2001. The list is as complete as possible. The editors apologize for any omissions and sincerely thank all those who have contributed to the quality of the journal by providing competent and timely reviews.

Baxter, R.
Boyce, W.
Brown, L.
Case, T.
Chotkowski, M.
Cole, R.
Duffy, W.
Friedman, D.
Fritz, C.
Geibel, J.
Gustafson, J.
Hayslette, S.
Hooton, B.
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Johnson, O.
Knutson, C.
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Lea, R.
Loft, E.
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Swift, P.
Swift, C.
Titus, R.
Updike, D.
Valentine, B.
Villepique, J.
Yoshiyama, R.

California Fish and Game 87(4):000-000 2001

INDEX TO VOLUME 87 (2001)

AUTHORS

Adams, P.B.: see Silberberg, Laidig, Adams, and Albin.

Albin, D.: see Silberberg, Laidig, Adams, and Albin.

Blankenship, D.S.: see Miller, Stemler, Yee, and Blankenship.

Charlton, K.G., D.W. Hird, and L.K. Spiegel: Trace Metal Concentrations in San Joaquin Kit Foxes from the Southern San Joaquin Valley of California, 45-50.

Clark, Jr., H.O.: Use of a Car Alarm Sequence in the Northern Mockingbird Repertoire, 115-116.

deWet-Oleson, K. and M. Love: Observations of Cleaning Behavior by Giant Kelpfish, *Heterostichus rostratus*, Island Kelpfish, *Alloclinus holderi*, Bluebanded Goby, *Lythrypnus dalli*, and Kelp Bass, *Paralabrax clathratus*, on Giant Sea Bass, *Stereolepis gigas*, 87-92.

Ebert, D.A.: First Eastern Pacific Records of the Longfin Mako Shark, *Isurus paucus*, Guitar-Manday, 1966, 117-121.

Hayes, D.B.: see Petrusso and Hayes.

Hayes, D.B.: see Petrusso and Hayes.

Hird, D.W.: see Charlton, Hird, and Spiegel.

Hovey, T.E.: First Observations on Spawning Behavior in the Giant Sea Bass, 61-66.

Hovey, T.E.: A Self-Contained Mobile Surgical Table for Fish, 67-71.

Jennings, M.R.: see Padgett-Flohr and Jennings.

Laidig, T.E.: see Silberberg, Laidig, Adams, and Albin.

Long, E.S. and R. Sweitzer: Museum Collection Records of Mountain Lions in California, 153-167.

Love, M.: see deWet-Oleson and Love.

Martin, B.A. and M.K. Saiki: Gut Contents of Juvenile Chinook Salmon from the Upper Sacramento River, California, during Spring 1998, 38-44.

Martin, B.A.: see Saiki and Martin.

Merz, J.E.: Association of Fall-Run Chinook Salmon Redds with Woody Debris in the Lower Mokelumne River, California, 51-60.

Merz, J.E.: Diet of Juvenile Fall-Run Chinook Salmon in the Lower Mokelumne River, California, 102-114.

Miller, M.R., C.L. Stemler, J.L. Yee, and D.S. Blankenship: Differences in Mourning Dove Productivity Among Three Time Periods at Gray Lodge Wildlife Area, California, 93-101.

Padgett-Flohr, G.E. and M.R. Jennings: An Economical Safe-House for Small Mammals in Pitfall Traps, 72-74.

Petrusso, P.A. and D.B. Hayes: Invertebrate Drift and Feeding Habits of Juvenile Chinook Salmon in the Upper Sacramento River, California, 1-18.

Petrusso, P.A. and D.B. Hayes: Condition of Juvenile Chinook Salmon in the Upper Sacramento River, California, 19-37.

Ripley, W.E.: In Memoriam - William A. Dill (1920-2000), 75-76.
Saidi, M.K. and B.A. Martin: Survey of Fishes and Environmental Conditions in Abbotts Lagoon, Point Reyes National Seashore, California, 123-138.
Saiki, M.K.: see Martin and Saiki.
Silberberg, K.A., T.E. Laidig, P.B. Adams, and D. Albin: Analysis of Maturity in Lingcod, *Ophiodon elongatus*, 139-152.
Spiegel, L.K.: see Charlton, Hird, and Spiegel.
Stemler, C.L.: see Miller, Stemler, Yee, and Blankenship.
Yee, J.L.: see Miller, Stemler, Yee, and Blankenship.

SUBJECT

Association, Fall-Run Chinook Salmon Redds with Woody Debris: in the Lower Mokelumne River, 51-60.
Behavior:
  Observations of Cleaning by Giant Kelpfish, Island Kelpfish, Bluebanded Goby, and Kelp Bass on Giant Sea Bass, 87-92.
  First Observations of Spawning in the Giant Sea Bass, 61-66.
Bluebanded Goby: Observations of Cleaning Behavior on Giant Sea Bass, 87-92.
California Fish and Game: Editorial Policy and Instructions to Authors, 77-86.
Chinook Salmon, Juvenile:
  Condition, 19-37.
  Diet of Fall-Run, Lower Mokelumne River, 102-114.
  Invertebrate Drift and Feeding Habits, 1-18.
  Gut Contents, Spring 1998, 38-44.
Chinook Salmon, Fall-Run:
  Diet of Juvenile, Lower Mokelumne River, 102-114.
  Association of Redds with Woody Debris in the Lower Mokelumne River, 51-60.
Condition: Juvenile Chinook Salmon in the Upper Sacramento River, 19-37.
Diet: Juvenile Fall-Run Chinook Salmon, in the Lower Mokelumne River, 102-114.
Differences: Mourning Dove Productivity Among Three Time Periods, Gray Lodge Wildlife Area, 93-101.
Eastern Pacific: First Records of Longfin Mako Shark, Guitar-Manday, 1966, 117-121.
Economical Safe-House, Small Mammals: in Pitfall Traps, 72-74.
Editorial Policy and Instructions to Authors: *California Fish and Game*, 77-86.
Environmental Conditions: Survey of Fishes and Environmental Conditions in Abbotts Lagoon, Point Reyes National Seashore, California, 123-138.
Feeding Habits, Juvenile Chinook Salmon: in Upper Sacramento River, 1-18.
Fish: A Self-Contained Mobile Surgical Table, 67-71.
Giant Sea Bass:
  First Observations of Spawning Behavior, 61-66.
  Observations of Cleaning Behavior by Giant Kelpfish, Island Kelpfish, Bluebanded Goby, and Kelp Bass, 87-92.
Giant Kelpfish: Observations of Cleaning Behavior on Giant Sea Bass, 87-92.

Gray Lodge Wildlife Area: Differences in Mourning Dove Productivity, 93-101.
Gut Contents: Juvenile Chinook Salmon in the Upper Sacramento River, Spring 1998, 38-44.
In Memoriam - William A. Dill (1910-2000), 75-76.
Invertebrate Drift, Juvenile Chinook Salmon: in Upper Sacramento River, 1-18.
Island Kelpfish: Observations of Cleaning Behavior on Giant Sea Bass, 87-92.
Kelp Bass: Observations of Cleaning Behavior on Giant Sea Bass, 87-92.
Lingcod: Analysis of Maturity in Lingcod, *Ophiodon elongatus*, 139-152.
Longfin, Mako Shark: First Eastern Pacific Records, Guitar-Manday, 1966, 117-121.
Lower Mokelumne River:
Diet of Juvenile Fall-Run Chinook Salmon, 102-114.
Association of Fall-Run Chinook Salmon Redds with Woody Debris, 51-60.
Mako, Longfin Shark: First Eastern Pacific Records, Guitar-Manday, 1966, 117-121.
Mountain Lions: Museum Collection Records in California, 153-167.
Mourning Dove: Differences in Productivity Among Three Time Periods, Gray Lodge Wildlife Area, 93-101.
Northern Mockingbird: Use of a Car Alarm Sequence in Repertoire, 115-116.
Observations:
Spawning Behavior in the Giant Sea Bass, 61-66.
Cleaning Behavior by Giant Kelpfish, Island Kelpfish, Bluebanded Goby, and Kelp Bass on Giant Sea Bass, 87-92.
Pitfall Traps: An Economical Safe-House for Small Mammals, 72-74.
Productivity, Differences: Mourning Dove, Gray Lodge Wildlife Area, 93-101.
Records, First: Longfin Mako Shark, Eastern Pacific, Guitar-Manday, 1966, 117-121.
San Joaquin Kit Foxes, Trace Metal Concentrations: Southern San Joaquin Valley, 45-50.
Self-Contained: Mobile Surgical Table for Fish, 67-71.
Shark, Longfin Mako: First Eastern Pacific Records, Guitar-Manday, 1966, 117-121.
Small Mammals: An Economical Safe-House in Pitfall Traps, 72-74.
Southern San Joaquin Valley: Trace Metal Concentrations in San Joaquin Kit Foxes, 45-50.
Spawning: First Observations of Behavior in the Giant Sea Bass, 61-66.
Surgical Table, Mobile: Self-Contained for Fish,67-71.
Survey: of Fishes and Environmental Conditions in Abbotts Lagoon, Point Reyes National Seashore, California, 123-138.
Trace Metal Concentrations, San Joaquin Kit Foxes: Southern San Joaquin Valley, 45-50.
Upper Sacramento River:
Gut Contents of Juvenile Chinook Salmon, Spring 1998, 38-44.
Condition of Juvenile Chinook Salmon, 19-37.
Invertebrate Drift and Feeding Habits of Juvenile Chinook Salmon, 1-18.
Use of a Car Alarm Sequence: Northern Mockingbird Repertoire, 115-116.

SCIENTIFIC NAMES

Alloclinus holderi, 87-92.
Alnus rhombifolia, 53.
Ambystoma californiense, 73.
Archoplites interruptus, 123, 128.
Atriplex spp., 46.
Baetidae (Ephemeroptera), 1, 7.
Blarina brevicauda, 49.
Brachyistius frenatus, 91.
Bromus spp., 46.
Catostomus occidentalis, 102, 103.
Chironomidae (Diptera), 1, 7.
Chromis punctipinnis, 91.
Clupea pallasi, 123, 128.
Cottus asper, 103, 127, 128.
Daphnia pulex, 106, 108, 111.
Embiotoca jacksoni, 91.
Engraulis sp., 123, 135.
Aucyclogobius newberryi, 124.
Gasterosteus aculeatus, 123, 127, 128.
Girella nigricans, 91.
Halichoeressemicinctus, 91.
Hermosilla azurea, 91.
Heterostichus rostratus, 87-92.
Hyperprosopon ellipticum, 123, 127, 128.
Hypsurus caryi, 91.
Ictalurus sp., 124.
Isurua paucus, 117-121.
Isurus alatus, 117.
Isurus oxyrinchus, 117, 120.
Leptocottus armatus, 123.
Lythrypnus dalli, 87-92.
Macrosystis pyrifera, 89.
Medialuna californiensis, 91.
Microtus pennsylvanicus, 49.
Micropterus salmoides, 123, 127, 128.
Mimus polyglottos, 115-116.
Morone saxatilis, 123, 128.
Mustela vison, 49.
Oncorhychus tshawytschar, 1-18, 19-37, 38-44, 51-60, 102-114.
Oncorhynchus mykiss, 102.
Ophiodon elongatus, 139, 141, 143, 144, 145, 146, 147, 148, 149, 150.
Oryjulis californiac, 91.

Paralabrax clathratus, 87-92.
Pelecanus occidentalis, 126.
Peromyscus leucopus, 49.
Phanerodon atripes, 91.
Phanerodon furcatus, 91.
Platichthys stellatus, 123.
Pomoxis nigromaculatus, 124.
Populus fremontii, 53.
Puma concolor, 153.
Quercus lobata, 53.
Rhachochilus vocca, 91.
Salix exigua, 53.
Semicossyphus pulcher, 91.
Sorex ornatus, 73.
Spirinchus thaleichthys, 123, 124, 128.
Stereolepis gigas, 61-66, 71, 87-92.
Triportheus guentheri, 31.
Vulpes macrotis mutica, 45-50.
Xenestius californiensis, 91.
Zalophus californianus, 89.
Zenaida macroura, 93-101.

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Editor, ***CALIFORNIA FISH AND GAME***
California Department of Fish and Game
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Sacramento CA 94244-2090

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